Water Resources Research Center
Annual Technical Report
FY 2017

Introduction

The Hawaii Water Resources Research Center (WRRC) was established at the University of Hawaii at Manoa in 1966. In 2013, WRRC was assigned the additional administrative responsibility as the Water Resources Research Institute serving American Samoa. Pago Pago, American Samoa is more than 2,600 miles from Honolulu—a 5 hour and 45 minute flight that is only offered by Hawaiian Airlines twice weekly. WRRC, from its base of operation in Honolulu, administers the American Samoa research program and stakeholder engagement despite the considerable complications of distance, time, and flight availability.

Freshwater resources in island states, including Hawaii and American Samoa, are under threat caused by the competing demands and contamination. Climate change and population growth have resulted in the diminishing supply of potable water. As the world faces escalating demands for suitable freshwater, the current usage is negatively affecting surface and groundwater supplies. This is more severe in island environments, which have a low buffering capacity and thus are highly vulnerable to climate change. WRRC has continued to address issues related to water quantity and quality critical to Hawaii, American Samoa, and the US affiliated Pacific. When compared to continental areas, such issues are more critical because of the Pacific Islands' geographic isolation, unique hydrological features, and small land areas. Over time, the concentration of our research varies in response to our growing understanding and regional need, but has focused consistently in the following areas:

- Groundwater Characterization Assessment and Modeling
- Groundwater Contamination, Drinking Water Supply Protection
- Recreational/Microbial Water Quality, Microbial Methods
- Wastewater Treatment Technology
- Wastewater Reuse/Disposal
- Watershed/Non-Point/Runoff
- Ocean Outfall Biomonitoring
- General Marine Water Quality
- Economics/Policy/Law
- Climate/Atmosphere/Precipitation/Evaporation/ Flooding
- Rainwater Catchment
- Streams/Lakes

Research Program Introduction

The University of Hawaii Water Resources Research Center (WRRC) seeks to fund four research projects annually from each of its federal allocations in support of water research in Hawaii and American Samoa. Beginning with the federal funding cycle in FY2016, WRRC embarked on converting its annual grants program to a biennial funding and award cycle. This change was implemented, in part, to better address the relatively small amount of funding provided through the WRRIP. Although the available funding provided to each research project (~$20k/year) in the new two-year cycle remains at a level to be deemed a pilot project, the longer term and additional funds allows for a deeper focus and more robust research engagement than projects designed for a single year. Further, in light of the co-administration with the University of Hawaii's Sea Grant College Program (Hawaii Sea Grant), we have aligned the funding cycles for these programs to allow for more engaged, interdisciplinary discussions among potential awardees around these competitive research opportunities. This in turn will undoubtedly foster an increase in synergistic outcomes for the state and region.

Due to delays in the congressional budgetary processes and the additional scrutiny of funding allocations, the funding for FY2017 projects was not received by WRRC until late June of 2017. This in turn resulted in late starts for the second year of research, and the ensuing requests by principle investigators for a no-cost extension in early FY2018. Therefore, presented below in the annual report are mostly progress reports. Additionally, there are three (3) final reports.

Studies during this reporting period addressed important and critical water problems for Hawaii and American Samoa. They are generally considered as those dealing with water conservation, drinking water and environmental quality, overall understanding of watershed processes, and student training and workforce development. Rather than repeat the information provided in the individual reports that follow, a general description and motivation for selected studies are provided in this introduction to illustrate the breadth, depth, and integration of the research programs for Hawaii and American Samoa.

Likely Hotspots for Algal Blooms: A Multi-Dimensional Analysis to Evaluate Seasonal Impact of Land-Based Sources of Pollution on the Health of American Samoa's Coasts examines land-use practices, such as agricultural regimes, significantly impacting the coastal biological communities through the contamination of submarine groundwater discharge (SGD). Sustainable land-use practices that put a premium on developing best practices for future farming and wastewater techniques, must consider the full ramifications of land-based sources of pollution, including severe 'nutrification,' an ecosystem level increase in nutrients that drives algal blooms. Moreover, the SGD link to coastal areas may be exacerbated by seasonal variation and global climate regimes such as El Niño.

Identifying Groundwater Flow and Contamination to Streams: Kahaluu Watershed, Oahu addresses watershed pollution due to pesticides, nutrients, and sediment. The contribution of baseflow to such problems can be significant. The contamination of nearshore waters by cesspools or other on-site disposal systems (OSDS) is a serious problem in Hawaii—which was declared as the State with the highest number of cesspools in the US—and all of them coastal. These systems can introduce sewage contamination by discharging groundwater to streams and the coastal and nearshore environments. To remedy the problem, there is a need to identify the contributing areas and OSDS that are the primary source of wastewater contamination to the streams and other open water bodies. This study ultimately seeks to provide critical information to land and water resource managers regarding the distribution and transport of pollutants for the optimal design of protective measures in a watershed.

Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa investigates surface water that can directly affect certain wells, such as those on Tutuila, American Samoa. On this island, the municipal water supply system is currently unable to provide potable drinking water to the island's growing population. In 2009, a boil-water advisory was issued throughout much of Tutuila's water service. However, the mechanisms and timescales of the rapid recharge of surface water to the wells remain unknown. This study is developing a better understanding of the mechanisms and timescales of recharge to Tutuila's wells.

Influence of Anthropogenic and Climatic Forcing on Water Quality Within a Tropical Coastal Ecosystem addresses the need to understand how a microbial community structure and function in tropical coastal estuaries drive the geochemical processes in response to climate forcing. Conditions in the Equatorial Pacific signify a developing El Niño but its current impact on environmental conditions in the Hawaiian Islands due to atmospheric tele-connections is not well defined. For Hawaii, El Niño events typically displace the subtropical jet stream, leading to decreased precipitation in boreal winter and slightly enhanced rainfall in summer as well as decreased trade winds. El Niño conditions promote temperature stratification of the water column, which will decrease oxygen availability and drive a shift in benthic biogeochemistry to more reducing conditions.

In addition, ***Microbial Communities and Sources of Bacteria in Honolulu's Water Supply***, a related study, addresses the fact that currently, except for a few fecal indicator bacteria being measured by State agencies, microbes residing in Hawaii aquifers are not well known. Hence, it is not possible to identify impacts, nor recovery of the compromised aquifers based on microbiological data. This is of great concern as impacts from population growth, climate change, and other hazards cannot be measured and evaluated without this essential data regarding characterization of microbial communities and sources of microbes in Honolulu's water supply. The main objectives of the study were to identify microbial community structure in the drinking water system and to determine the source of indicator bacteria.

Conservation related studies such as ***Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa*** address the fact that island communities, such as Hawaii and American Samoa, face mounting demands on water supply due to increased consumption and climate change. The latter can cause lower rainfalls, decreased ground recharge, and redirection of rainfalls over watersheds—all of which stress the pre-existing ground supply of potable water. Concerns about water shortages make it necessary to optimize the use of valuable water resources. Options include watershed repair, rainwater capture, and water reuse. Irrigation scheduling is also an important measure that addresses over irrigation, which not only wastes water and energy, but impairs the quality of surface and groundwater, and possibly the nearshore coastal waters. Crop yield decrease is also possible. The negative effects of under irrigation would obviously diminish crop yields and thereby decrease profit margins.

Waste generation and disposal is a serious problem, especially on island environments. Discharging waste into the ocean or through cesspools and septic systems may cause water quality problems. ***Wastewater Treatment for Point Source Processing and Resuse*** engages in developing innovative techniques for wastewater treatment and reuse, which represent an attractive alternative.

Rainforests are recognized for their role in helping the water cycle by transpiring water to the atmosphere and contributing to rain cloud formation. Forests also protect the soil layers that store water and prevent soil erosion. The study ***Understanding the Hydrology of a Rainforest Watershed in Hawaii*** was motivated by the need to understand the response of rainforests to unique precipitation patterns at a watershed scale. For example, in some locations in Hawaii, though the rainfall intensity has increased, total rainfall has been on the decline in the last two decades and stream flow is subsequently subsiding. These analyses address the various hydrologic mechanisms, such as flow paths, groundwater recharge, evapotranspiration, and time of concentration.

Evaluating Student Training and STEM Workforce Development at the National Institutes for Water Resources leverages the capacity of WRRC (at the University of Hawaii) to demonstrate national leadership for the benefit of the national program in assessing the Water Resources Research Act Program's significant contribution to capacity building in the form of student mentoring and training in water research and its contribution to the USGS workforce at large.

Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa

Basic Information

Title:	Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa
Project Number:	2016AS454B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Categories:	Water Quality, Water Use, Solute Transport
Descriptors:	None
Principal Investigators:	Marek Kirs, Craig R Glenn

Publications

1. There are no publications for 2016.
2. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017AS471B** “Assessing recharge mechanisms of groundwater under the influence of surface water with isotopic and microbiological tracers, Tutuila, American Samoa” by Principal Investigator Marek Kirs.

Stream pesticide and nutrient loads from baseflow, surface runoff and sediment contributions on Tutuila Island, American Samoa

Basic Information

Title:	Stream pesticide and nutrient loads from baseflow, surface runoff and sediment contributions on Tutuila Island, American Samoa
Project Number:	2016AS455B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Categories:	Models, Sediments, Water Quality
Descriptors:	None
Principal Investigators:	Henrieta Dulai

Publications

1. There are no publications for 2016.
2. Welch, E., 2018, “Field assessment and groundwater modeling of pesticide distribution in the Faga‘alu watershed in Tutuila, American Samoa,” BS Thesis, Global Environmental Sciences, SOEST, University of Hawaii at Manoa, Honolulu, HI, 90 p.
3. Shuler, C.K., O.T. Leta, and H. Dulai, 2017, “Groundwater-stream water interaction, groundwater discharge, and quantification of associated nutrient loading in Fagaalu watershed, American Samoa,” 2017 GSA Cordilleran section 113th annual meeting, Honolulu, Hawaii, May 23–25. Vol. 49(4), doi: 10.1130/abs/2017CD-292708. https://gsa.confex.com/gsa/2017CD/webprogram/Paper292708.html. Paper No. 6-6.
4. Welch, E., H. Dulai, A.I. El-Kadi, and C. Shuler, 2017, “Groundwater contribution to glyphosate concentrations in the Fagaalu watershed, American Samoa,” 2017 GSA Cordilleran section 113th annual meeting, Honolulu, Hawaii, May 23–25. Vol. 49(4), doi: 10.1130/abs/2017CD-292708. Paper No. 15-3.
5. Leta, O.T., H. Dulai, A.I. El-Kadi, A.M. Messina, and T.W. Biggs, 2017, “Assessing sediment yield and the effect of best management practices on sediment yield reduction for Tutuila island, American Samoa,” Poster presented at 2017 AGU Fall Meeting, New Orleans, LA, December 11–15.
6. Welch, E., H. Dulai. A.I. El-Kadi, and C. Shuler, 2017, “Field assessment and groundwater modeling of pesticide distribution in the Faga‘alu watershed in Tutuila, American Samoa,” Poster presented at 2017 AGU Fall Meeting, New Orleans, LA, December 11–15.
7. Welch, E., H. Dulai, A.I. El-Kadi, and C. Shuler, 2018, “Field assessment and groundwater modeling of pesticide distribution in the Faga‘alu watershed in Tutuila, American Samoa,” Poster presented at Albert L. Tester Symposium, University of Hawaii at Manoa, Honolulu, HI, April 2018.

FINAL REPORT

Stream Pesticide and Nutrient Loads from Baseflow, Surface Runoff and Sediment Contributions on Tutuila Island, American Samoa

May 2016

Henrietta Dulai

WRRC-2018-01

Project Number: 2016AS455B

Water Resources Research Center
University of Hawaii at Manoa
Honolulu, Hawaii

Abstract

Fagaalu watershed, located on the island of Tutuila, American Samoa was identified as a priority watershed due to the reduction of stream water quality from the anthropogenic activity yielding high nutrient and sediment loads. This study estimated the sediment yield to the Fagaalu Stream from existing land use types and assessed the impact of the best management practices on the sediment yield reduction. We found that the bare land with quarry activity yielded the highest annual average sediment yield, and the forested part of the watershed the lowest. Treating the quarry area with stone bund showed the highest sediment yield reduction of 85% in comparison to other treatment scenarios. In addition, the study estimated selected pesticide fluxes into the coastline emphasizing groundwater pathways as a mode of pesticide transport. The calculated groundwater discharge to the bay was 4,129 m^3/d and the corresponding pesticide fluxes were 482 mg/d and 5,519 mg/d of glyphosate and dichlorodiphenyltrichloroethane (DDT), respectively.

Problem and Research Objectives

The project provides information on the distribution and transport of pollutants (sediments and pesticides) in the Fagaalu watershed, on the island of Tutuila in American Samoa (Figure 1). The watershed is heavily impacted by anthropogenic activity yielding high sediment, pesticide, and nutrient loads to the coastal reef. The project utilizes the combination of a watershed water budget model linked to a groundwater model, along with stream discharge, pesticide, nutrient, and sediment measurements.

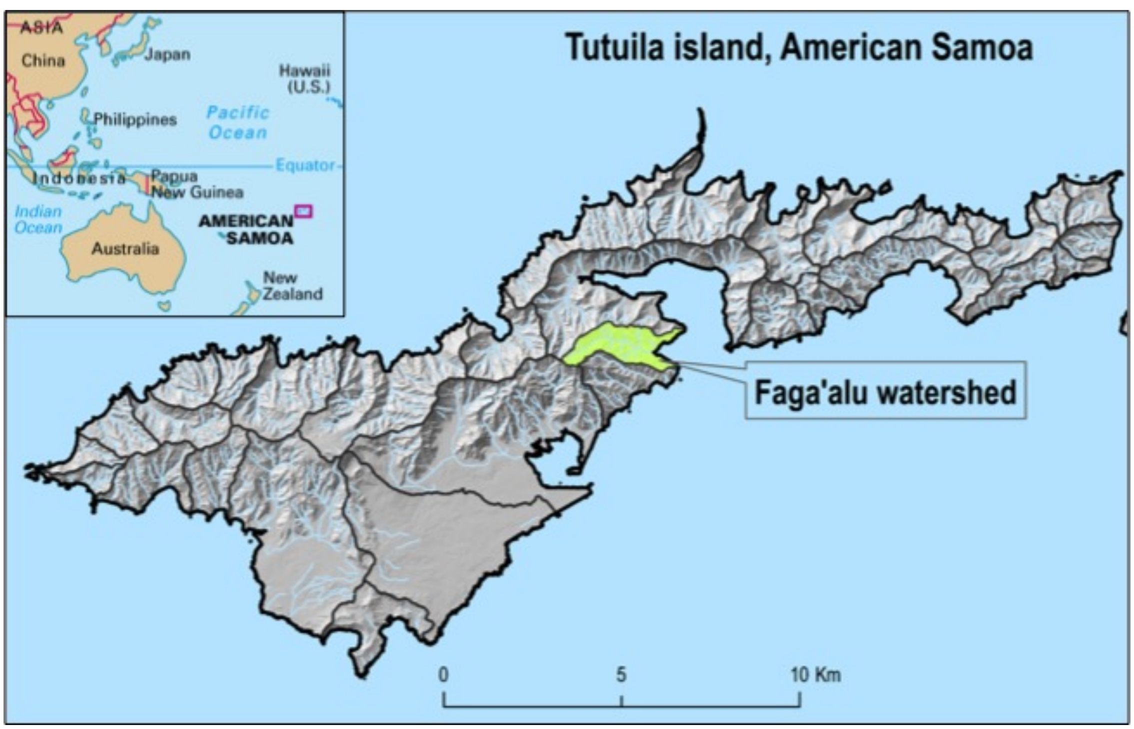

Figure 1. Location of Fagaalu watershed on Tutuila, American Samoa.

To assess the sediment fluxes, the objectives were to (1) use the Soil and Water Assessment Tool (SWAT) model to estimate the watershed water budgets, including stream discharge and recharge to the aquifer; (2) adapt the SWAT model to estimate the sediment yield and contribution of different land use types to the stream sediment budget; and (3) assess the impact of three best management practice (BMP) scenarios (stone bund, vegetative filter strip [VFS], and retention pond) on the sediment yield reduction.

To assess the pesticide fluxes, the objectives were to (1) measure stream and groundwater pesticide concentrations; (2) develop a groundwater flow model (MODFLOW) for the aquifer using stream discharge, groundwater elevation, and geochemical tracer derived baseflow estimates; and (3) compile an inventory for selected pesticides in groundwater and selected streams across the island of Tutuila.

This helped identify which pesticides are of concern and which areas are most affected. In a targeted study focusing on the Fagaalu watershed, the study located and quantified the contribution of groundwater and associated pesticide fluxes to the baseflow in the stream and as submarine groundwater discharge (SGD) to the ocean. In addition, a groundwater model (MODPATH) was used to simulate groundwater flowpaths to track subsurface pesticide pathways.

Methodology

The suspended sediment (SS) modeling utilized a previously developed SWAT model for streamflow modeling of the Fagaalu watershed. Geo-spatial and hydro-meteorological data, including sediment readings from gauging stations were utilized in constructing the model. The model was developed, calibrated, and validated for the period 2005 to 2014. Following global parameter sensitivity analysis, the model was calibrated against observed SS by using the parameters to which the model showed high sensitivity. The model calibration and validation processes were enhanced by the availability of observed suspended sediment concentration and streamflow data (2012 to 2014) at Fagaalu's Dam and Lyndon Baines Johnson (LBJ) Tropical Medical Center stations, collected by collaborators from the Department of Geography, San Diego State University (SDSU) (A. Messina, personal communication, 2016). The effort also included data quality check and assurance. Three scenarios of best management practices were tested to evaluate their effectiveness in reducing stream sediment loads from different land use categories.

To determine pesticide fluxes, four pesticides were selected based on information obtained from collaborators at the American Samoa Community College (ASCC) (Dr. Mark Schmaedick), the American Samoa Environmental Protection Agency (AS-EPA), and the American Samoan National Association of State Departments of Agriculture (NASDA). In the next step, research focused on the Fagaalu watershed and investigated the potential of groundwater as a vector of pesticide transport into Fagaalu Bay. Two processes were evaluated (1) groundwater contribution to the stream and associated pesticide fluxes, and (2) direct groundwater discharge into the bay via springs, seepage, and associated pesticide fluxes. These processes were identified and quantified using geochemical tracing techniques using radon as a groundwater tracer. Combining pesticide distribution in Fagaalu with a MODFLOW numerical model, pesticide fluxes were determined in groundwater and MODPATH was used to source where their application may be located within the watershed. The Groundwater Modeling System (GMS) groundwater model used recharge determined by SWAT and was calibrated against the stream baseflow and groundwater level in the aquifer. A steady-state model was used to reconstruct the groundwater levels and flow paths. Flow paths were extracted for all groundwater samples collected across the watershed (well, river bank groundwater, coastal springs). The flow paths were then used to connect the measured pesticide concentrations to land use categories in the watershed to determine possible migration paths.

Principal Findings and Significance

Assessing Sediment Yield and the Effect of Best Management Practices on Sediment Yield Reduction for Tutuila Island, American Samoa

We found that the SWAT well reproduced the observed daily streamflow and sediment load temporal evolutions. All statistical indexes show acceptable model performance, with as much as 94% of observations bracketed (p-factor) within the 95% prediction uncertainty (Figure 2).

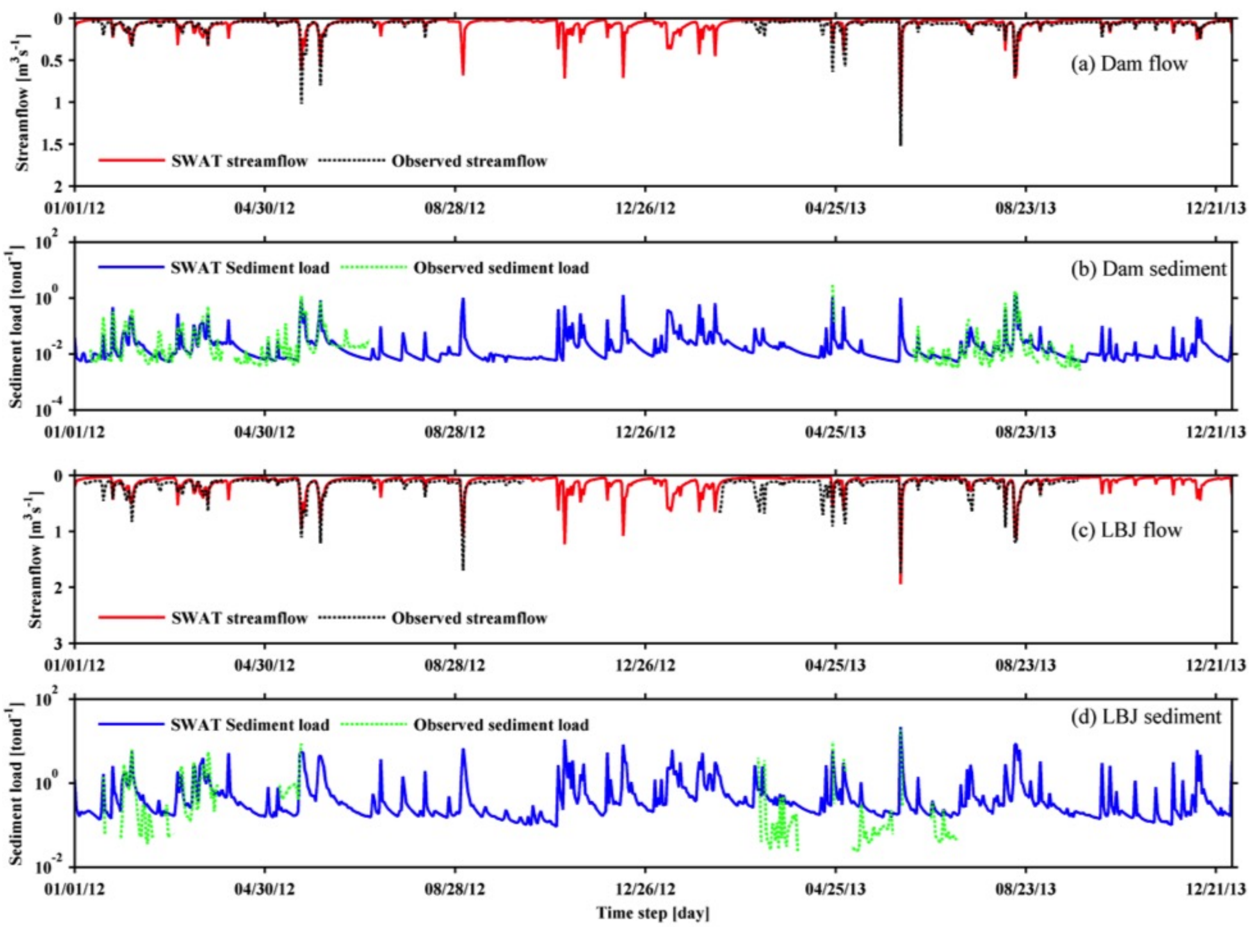

Figure 2. Observed and simulated daily streamflow and suspended sediment load at (a and b) upstream and (c and d) downstream/populated area stations of Fagaalu watershed.

Overall, findings indicated that while the upland forested watershed part of Fagaalu generates relatively lower amounts of suspended sediment fluxes, the lower, human-disturbed and urbanized part of the watershed produces a significant amount of sediment, signifying the high impact of anthropogenic activities on sediment yield. This may cause considerable sediment loading and associated sediment-attached pollutant fluxes to the coastal reef. Bare land (quarry area) contributed over 60% of the watershed's sediment yield, followed by cultivated land and forested areas. In the model VFS and stone bund treatments were applied to the quarry area and cultivated land uses, and a retention pond to the quarry area. This study analyzed three BMP scenarios, and also observed the suspended sediment concentration (SSC) in 2016—collected during the post-pond mitigation assessment below the quarry area—which was used to validate the SWAT accuracy after the pond implementation scenario. SWAT reasonably reproduced the observed SSC after the pond implementation, signifying the applicability of the model for future scenarios. When compared to the baseline, all the applied BMP scenarios reduced the sediment yield from the quarry area by more than 40%. Stone bund showed the highest reduction in sediment yield from the quarry area when compared to the currently implemented retention pond (Figure 3).

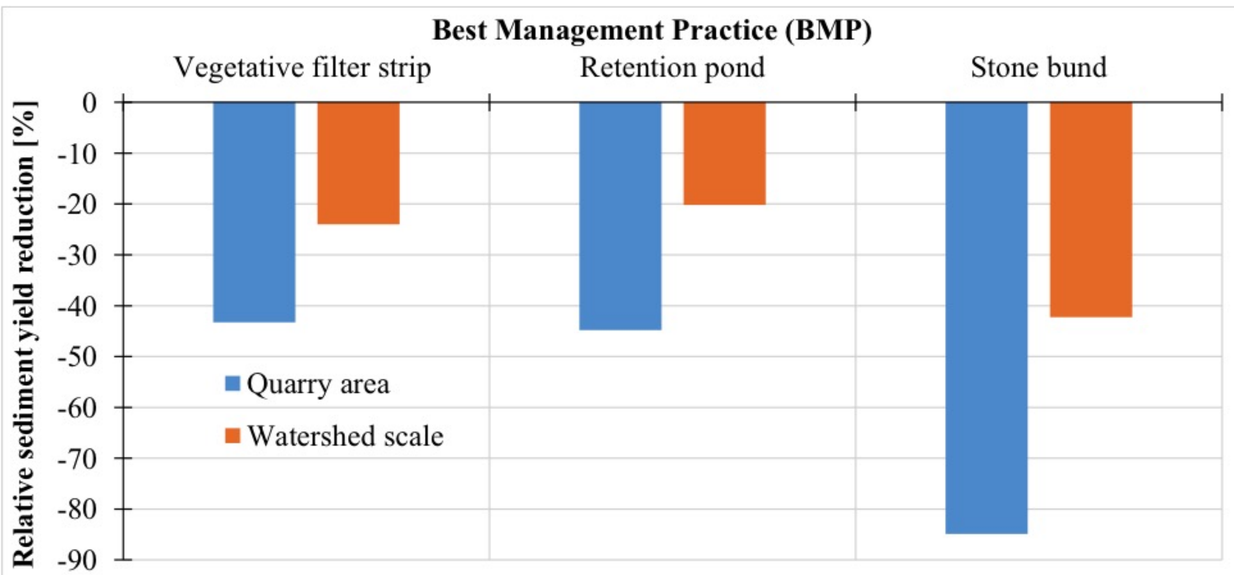

Figure 3. The relative sediment yield reduction of three BMPs compared to baseline values at the quarry area and watershed scale. The vegetative filter strip and stone bund scenarios at watershed scale also include reduction from the cultivated land.

Field Assessment and Groundwater Modeling of Pesticide Distribution in the Fagaalu Watershed in Tutuila, American Samoa

In order to assess groundwater's role as a pollution pathway, groundwater and stream water samples were collected across the island and analyzed for their pesticide content. This study looked at four selected pesticides: glyphosate, DDT, imidacloprid, and azoxystrobin. Statistical analysis of island-wide pesticide concentrations using analysis of variance revealed that at 95% significance, there is no difference in surface and groundwater glyphosate concentrations. Imidacloprid and DDT, however, showed a difference in surface and groundwater concentrations across the island with higher concentrations present in groundwater. Glyphosate was detected in lower concentrations in samples from the eastern and western coastal regions of Tutuila, while the central region of the island spanning from the Tafuna Plain to the Pago Pago Harbor showed more elevated concentrations (64% higher than the island-wide average of 0.075 ppb). The Fagaalu watershed in particular showed higher concentrations of the herbicide than anywhere else sampled. The watershed average was 0.141 ppb, which is 88% higher than the island-wide average. The highest concentration found during this study was the southern coastal spring in Fagaalu, which had 0.301 ppb of glyphosate. We used the MODFLOW model created for the Fagaalu aquifer to estimate the direct discharge of groundwater into the coastal ocean. The calculated SGD across the boundary was 4,129 m^3/d and the glyphosate flux by SGD was 482 mg/d. To show the importance of groundwater pathways, the objective of the study was to also estimate groundwater discharge into the stream. The flow budget for the upper reach of the Fagaalu Stream and associated glyphosate fluxes were dominated by groundwater inputs, representing a contribution to the stream flow of 91% and to total glyphosate flux of 89%. Groundwater contribution to the stream was only 24% in the lower reach with glyphosate fluxes accounting for 27% of the total stream discharge. The insecticide imidacloprid was found at low concentrations (< 0.172 ppb), with highest levels on the Tafuna Plain in the central part of the island. Groundwater tended to have two times the mean concentrations than the stream samples (0.08 ppb to 0.04 ppb, respectively). Although the fungicide azoxystrobin is listed as legal for use in American Samoa, no traces of the chemical was found in any samples tested across Tutuila. Although in highest concentrations on the Tafuna Plain, DDT was found in all but two samples tested across the island. The ubiquitous presence of the insecticide, across developed and undeveloped sites, is likely a result of airplane flyovers for island-wide spraying in the mid-twentieth century. Although DDT has been banned in American Samoa since 1972, its persistence continues to be observed in the soils and waters of Tutuila. The DDT contribution to Fagaalu Bay via SGD was estimated to be 5,519 mg/d. Groundwater-derived DDT fluxes into the stream represented 91% of the total stream DDT flux in the upper reach and 28% in the lower part of the stream. Thus the overall conclusion of the study is that groundwater in the form of SGD or stream baseflow is just as important as surface water in distributing water-soluble pesticides across Tutuila.

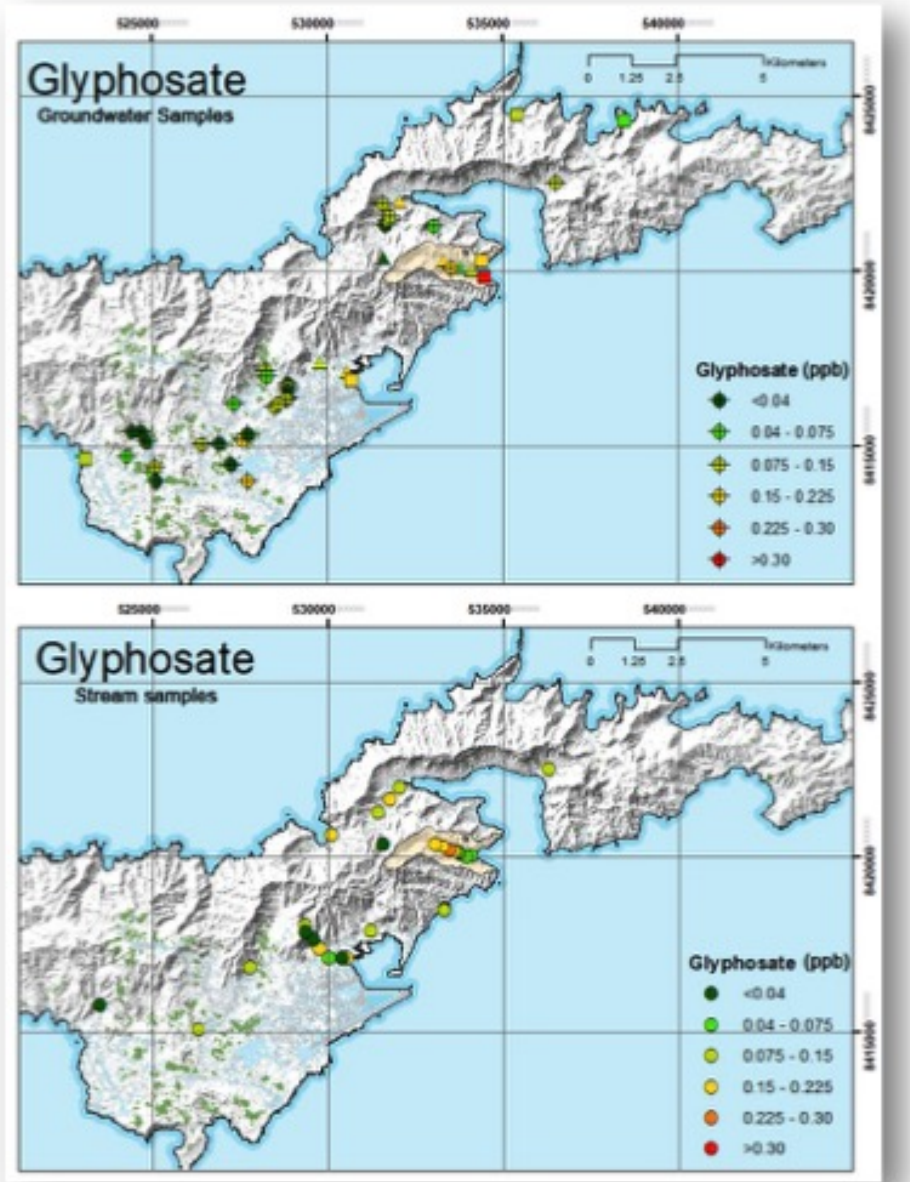

Figure 4. Distribution of glyphosate in groundwater and stream samples.

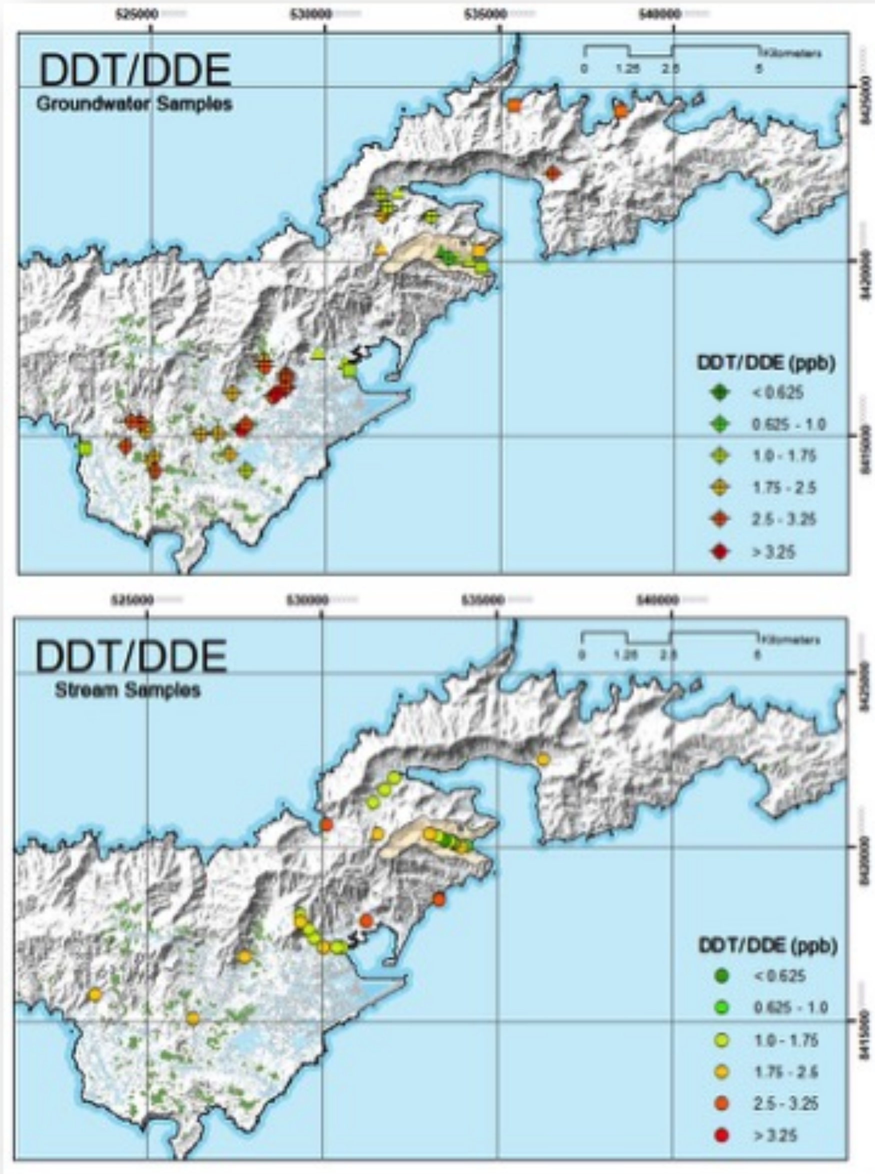

Figure 5. Distribution of DDT and its breakdown product dichlorodiphenyldichloroethylene (DDE) in groundwater and stream samples.

The spatial land-use and groundwater flow path analysis using MODPATH revealed that certain highly developed areas have higher pesticide concentrations than undeveloped areas. Glyphosate showed elevated concentrations in the Tafuna Plain, Pago Pago, and Fagaalu watersheds, while the presence of imidacloprid was most evident on the densely populated Tafuna Plain. The higher concentrations in developed rather than rural areas, reflects the abundant practice of backyard agriculture and personal pesticide use on the island, rather than large-scale farming operations. DDT was the only pesticide in this study that showed an even distribution across the island, which can be explained by its mode of application via airplane spraying in the mid-twentieth century.

Likely hotspots for algal blooms: A multi-dimensional analysis to evaluate seasonal impact of land-based sources of pollution on the health of American Samoa’s coasts

Basic Information

Title:	Likely hotspots for algal blooms: A multi-dimensional analysis to evaluate seasonal impact of land-based sources of pollution on the health of American Samoa’s coasts
Project Number:	2016AS456B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Categories:	Water Quality, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Rosanna Alegado, Celia Smith

Publications

1. Shuler, Chris, 2017, “Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa” Ph.D. Dissertation, Department of Geology and Geophyics, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Amato, D.W., C.M. Smith, C. Schuler, H. Duali, C.R. Glenn, V. Gibson, L. Baker, and R.A. Alegado, “Algal bioassays identify sources of land-based nutrient pollution in Hawaii and American Samoa,” Oral Presentation in 13th International Coral Reef Symposium, Honolulu, HI, June 2016.
3. Shuler, C.K., D. Amato, V. Gibson, L. Baker, A.N. Olguin, H. Dulai, C.M. Smith, and R.A. Alegado, “Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa,” Oral Presentation in American Society for Limnology and Oceanography Meeting, Honolulu, HI, February 2017.
4. Amato, D.W., C. Shuler, V. Gibson, L. Baker, R.A. Alegado, C.R. Glenn, H. Dulai, C.M. Smith, “Algal bioassays show land-based, anthropogenic nitrogen is delivered to reef biota by groundwater in American Samoa.” (in preparation)
5. Shuler, C.K., D. Amato, V. Gibson, L. Baker, A.N. Olguin, H. Dulai, C.M. Smith, R. Alegado, “Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa.” (in preparation)
6. Shuler, C., “Groundwater quality, quantity, and hydrogeology of Tutuila Island, American Samoa,” Ph.D. dissertation, Department of Geology and Geophysics, University of Hawaii at Manoa, Honolulu, HI. (in preparation)

Abstract

Land-use practices can impact nearby coastal biota by tainting submarine groundwater discharge (SGD) to adjacent reefs (Amato 2015, Amato et al. 2016) by increasing local nutrient availability and driving algal blooms (Van Houtan et al. 2010, Van Houtan et al. 2014). In American Samoa, land-based sources of pollution may be exacerbated by seasonal variation in rainfall (fine scale phenomena) and global climate regimes such as El Niño (large scale phenomena). We identified coastal sites tainted by SGD along a human-use gradient on Tutuila, using fine scale variations in coastal biota of Tutuila via algal bioassay parameters ($\partial^{15}N$ and %N), modified microbial communities assessed by next generation sequencing, and macro-benthic surveys at impacted sites and reference sites. Co-registered microbial community analysis diversity enabled *identification of impacted and healthy sites.* Importantly, this multi-year and continued multi-dimensional study to better understand SGD and responses in biota may aid coastal resource managers.

Problem and Research Objectives

Since 2003, high intensity developed land use in American Samoa has increased to include an additional 135.8 acres. Consequently, University of Hawaii (UH) researchers are currently working to establish the extent of the nutrient loading into the groundwater on the land, specifically areas that are approximately one mile from the coastal regions.

In 2015, a draft of the Coastal Zone Management Act: Section 309 Assessment and Strategy report by the American Samoa Coastal Management Program (American Samoa 2015) indicated that water pollution, dumping trash, and the location of piggeries are being considered for the Phase 2 program activities for the coastal wetlands. Since July 2015 our study has evaluated the impact of the potential nutrient loading on the health of the coastal biota of Tutuila.

The objectives of this research are to examine the features of the three emerging indicators of ecosystem health for the targeted sites on the south shore of Tutuila that bracket the original location of anticipated nutrient loading via SGD. These parameters of impaired ecosystem are variations in $\delta^{15}N$ and %N in plant tissues, as well as modified microbial communities as assessed by the whole sample genomic assessments. Control or reference sites will be characterized to identify the taxa under less impacted conditions, thus allowing us to view the variation in these parameters along a gradient—from healthy to impacted coastal regions. This research will extend our earlier funded project and can lead to the use of new innovative technologies for real-time detection of hot spots for algal blooms and bacterial indicator species in coastal regions.

Methodology

Our team has pioneered use of non-calcified reef algae as algal tissue indicators for $\delta^{15}N$ and %N. To enable robust comparison of the algal tissue indicators among locations, we selected a single species, *Hypnea pannosa* (Rhodophyta), for inter-comparison based on our previous benthic survey. After collecting *H. pannosa* from coastal sites, we cultivated the algae under conditions to deplete their internal N stores then deployed these algae at coastal sites for set periods of time to measure tissue accumulated $\delta^{15}N$ and %N.

Principal Findings and Significance

Roughly 70% of our samples were analyzed. In general, comparison of the 2016 field season data showed very similar results to our 2015 data set. The four principal locations using algal tissue $\partial^{15}N$ indicated nearly identical trends to our 2015 data set. The average algal tissue $\partial^{15}N$ values were highest at both extensively impacted locations (Fagaalu and Pala Lagoon) and lowest at minimally impacted locations (Vatia and Oa), which indicated wastewater was a likely source of N to the coastal waters of both Fagaalu and Pala Lagoon.

Not surprisingly, the $\partial^{15}N$ values of the deployed *H. pannosa* showed very similar trends among locations to the averaged values of the collected samples (all species collected *in situ*) from both field seasons. In addition, a significant positive relationship was found between tissue $\partial^{15}N$ and N% in the deployed *H. pannosa*. This indicated that the samples with elevated $\partial^{15}N$ values generally had more N stored in their tissues. Therefore, coastal reef areas where wastewater was a source of N may have higher concentrations of biologically available N in the water column. This hypothesis was supported by our coastal water nutrient results from both 2015 and 2016. Inorganic nitrogen concentrations of marine surface water were highly elevated above the ambient oceanic values in Pala Lagoon. One 2016 sample from Pala Lagoon had a concentration of 48 µmol/L N+N. Similar to our 2015 data set, both water samples and algal samples detected “hot spots” for wastewater derived N in Vatia and Pala Lagoon near a prominent coastal spring.

Although we anticipated the variations in our results between sampling years due to El Niño effects both sampling years also showed similar trends among the locations. This was not unexpected as the El Niño effects in American Samoa were very mild compared to other Pacific regions during the period of study (Summer of 2015 to Summer of 2016). Algal bioassays indicated that coastal water chemistry at our study locations did not change over the year.

We anticipate a similar result in the microbial community data set—microbial samples have been collected, DNA extracted, and DNA sequencing is underway. Although data and results are still pending, we anticipate that water quality at our study locations in American Samoa will be closely linked with human density and the N input from piggeries other agricultural practices.

We were unable to complete the project by 28 February 2018 because funding was not received for FY2017 (Year 2) until after April 2017. In March 2017 we were informed that WRRIP grants would receive approximately15% of the proposed funding. WRRC was not able to provide these funds until after 28 April 2017. As a result, we were unable to make purchases in time for our Year 2 field season in American Samoa, which typically spans two weeks in July to August. We have reserved a significant portion of our remaining funds in anticipation of a field season in Summer 2018.

Proposals or Projects Initiated Based on this Research

Coral tissue samples and corresponding water column nutrients were collected in collaboration with a project funded by the National Fish and Wildlife Foundation: "Setting Nutrient Thresholds Using Coral and Microbial Genomics," Dr. Craig Nelson, Principal Investigator, UH Manoa Department of Oceanography and Sea Grant College Program. This project sought to relate the composition of coral-associated microbial communities (the microbiome of the coral holobiont) to patterns of nutrient enrichment around Tutuila. Coral tissue samples were collected from five locations, sampling ten corals each of *Pocillopora damicornis* and *Porites cylindrica* at each site, and corresponding water column measurements of nitrate, ammonium, and phosphate were used to assess relative nutrient enrichment among the five sites. Preliminary results indicated that nutrient enriched sites enriched several families of bacteria associated with coral tissue, suggesting that these taxa may be promising candidates to use for monitoring chronic nutrient enrichment responses in the coral holobiont.

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Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa

Basic Information

Title:	Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa
Project Number:	2016AS457B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Irrigation, Agriculture, Hydrology
Descriptors:	None
Principal Investigators:	Sayed Bateni

Publications

1. There are no publications for 2016.
2. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017AS472B** “Real-time optimization of irrigation scheduling for farmlands in American Samoa” by Principal Investigator Sayed M. Bateni.

Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa.

Basic Information

Title:	Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa.
Project Number:	2017AS471B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Categories:	Water Quality, Water Supply, Solute Transport
Descriptors:	None
Principal Investigators:	Marek Kirs, Craig R Glenn

Publications

1. Shuler, C., "Groundwater quality, quantity, and hydrogeology of Tutuila Island, American Samoa," Ph.D. dissertation, Department of Geology and Geophysics, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Shuler, C.K., A.I. El-Kadi, H. Dulai, M. Kirs, C.R. Glenn, and R. DeWees, " An isotopic and microbiological multi-tracer approach to assessing recharge mechanisms in surface water affected wells on Tutuila, American Samoa," Poster presented at 2017 Geological Society of America (GSA) Annual Meeting, Seattle Convention Center Seattle, WA, October 2017.
3. Shuler, C.K., A.I. El-Kadi, H. Dulai, M. Kirs, C.R. Glenn, K.E. Mariner, R. DeWees, M. Schmaedick, I. Gurr, M. Comeros, M. Erickson, and T. Bodell, " Connecting hydrologic research and management in American Samoa through collaboration and capacity building," Poster Presented at 2017 American Geophysical Union Annual Meeting, New Orleans Convention Center, New Orleans, LA, December 2017.

Abstract

Since 2009, the municipal water on Tutuila, American Samoa has been subject to a boil-water-advisory. A number of wells are designated as groundwater under the direct influence of surface water where significant turbidity and bacteria spikes correlate with heavy rainfall events. It has remained unclear whether surface water reaches wells through improperly sealed well casings, or through the aquifer matrix itself. In this study, geochemical tracers were used to constrain recharge timing and transport from the surface to the wells. Tracers included water isotopes (δ^2H and δ^{18}O), indicator bacteria, and turbidity levels. The results indicated the rapid recharge of surface water occurs quickly, within 7 to 38 hours of heavy rainfall, which corresponded to estimated groundwater velocities in permeable aquifer material, as opposed to faulty casings. These conclusions suggest the aquifer lacks the filtration capacity to remove surface contaminants, and thus abandonment of the Tafuna Well Field is recommended over rehabilitation of the existing wells.

Problem and Research Objectives

On Tutuila, American Samoa, portions of the municipal water supply system have been afflicted with a boil-water advisory since 2010 due to elevated turbidity and *Escherichia coli* detections in some of the island's highest producing supply wells (ASEPA 2016). This has been attributed to short groundwater recharge times during heavy rain events, necessitating these wells be designated as Groundwater Under the Direct Influence (GUDI) of surface water (USEPA 2006). Although it is clear that surface water reaches these wells during rain events, the mechanism of contamination has not yet been constrained. Two hypothesized mechanisms are (1) highly-permeable aquifer material allows surface water to infiltrate and contaminate the entire aquifer, or (2) improperly constructed well casings or packings allow small amounts of localized surface water to infiltrate through the well bore itself. If well casing integrity is the primary problem, repair or installation of new wells would allow continued use of existing water delivery infrastructure. However, if the aquifer itself has low-filtration capacity, abandonment of the entire well field or installation of costly surface water treatment facilities would be necessary to solve the issue.

Objectives for this study are to develop a better understanding of the mechanisms and timescales of recharge to Tutuila's GUDI wells. The validity of the hypotheses presented above are examined by comparing values of environmental tracers with rainfall records to determine the average travel time of surface water constituents to each GUDI well. Three independent datasets are used: (1) turbidity and indicator bacteria from previous American Samoa Power Authority (ASPA) GUDI well studies, (2) water isotope (δ^{18}O and δ^2H) values in precipitation and groundwater taken over short and long time resolutions, and (3) recently taken indicator bacteria samples from GUDI and non-GUDI wells. Additionally, video logs of ASPA wells were examined to visually assess well construction and casing integrity.

Methodology

Rainfall-Event Scale Turbidity Response

Turbidity and local rainfall data were provided in raw form by the ASPA. For this study, the raw ASPA turbidly data was filtered and reanalyzed to identify significant turbidity peaks correlated with heavy rainfall events. *E. coli* concentrations were also plotted with turbidity data to visually assess correlation between bacteria and turbidity. Turbidity peak durations, times between rain event, start of peak, times between rain event, and top of peak were calculated for each event. Travel times were compared to analytically derived estimates of expected groundwater flow velocities to elucidate probable mechanisms of contamination.

Microbial Indicators in GUDI and Non-GUDI Wells

Presence of short-lived endogenous or soil bacteria species in groundwater indicates both lack of filtration capacity in aquifers (Entry and Farmer 2001) and short groundwater travel times, since *E. coli* die off rates in this environment may be greater than 50% per day (Foppen and Schijven 2006). Bacteriological tracers have previously been applied in numerous settings for determining groundwater travel times through preferential pathways that lie at the statistically rapid end of flow velocity distributions (Barrell and Rowland 1979, Taylor et al. 2004, Godfrey et al. 2005). For this study, selected GUDI and non-GUDI wells were sampled at monthly intervals and during high-rain events for total coliform (TC) and *E. coli* bacteria with Colilert-18® tests in Quanti-Tray®/2000 format. Correlation between bacteria concentrations and rainfall were assessed to determine microbial transit velocities between the surface and well pumps.

Water isotopes ($\delta^{18}O$ and $\delta^{2}H$) in precipitation and groundwater

Comparison of $\delta^{18}O$ and $\delta^{2}H$ compositions in precipitation and groundwater are commonly used in tropical and island environments to understand recharge sources and elevations (Scholl et al. 1996, Rhodes et al. 2006, Fackrell 2016). However, use of this tracer to assess recharge timing and volume of recent rainfall contributions to groundwater on short time scales constitutes a novel approach, and this study demonstrated the utility of this method for validation or comparison with other tracers. Water isotope samples were collected on a monthly basis for a three-year period from production wells and rainfall collectors located throughout the island. Additionally, short-term variation was assessed with collection over a three-week rainfall-event period at seven GUDI wells, two non-GUDI wells and two precipitation collectors.

Principal Findings and Significance

Reanalyzed ASPA turbidity data showed clearly defined rainfall-event related turbidity peaks up to 6 NTU, in all of the Tafuna wells, which are also all designated as GUDI wells. Peaks in Tafuna wells generally had sharp onsets an average of 17 hours after rainfalls, reached maximum values an average of 36 hours later, and lasted for a duration of 36 to 265 hours. These travel times are consistent with estimated groundwater velocities in the Tafuna aquifer, as based on hydraulic conductivity data from Izuka et al. (2007). Where observed in other, non-GUDI well fields, peaks were more dome shaped and response times were generally slower. The only exception was in one well, Malaeloa 169. Although designated as non-GUDI, a video log of this well during a rainfall event showed a hole in the casing that discharged water into the well at 41 ft below ground surface. The turbidity profile for Well 169 showed a dramatic (25 NTU) turbidity peak, starting 3 hours after a rain event, peaking in 4 hours, and with a duration of only 15 hours. The response at Well 169 demonstrates how faulty casings affect water quality, whereas the responses observed in the Tafuna wells are most likely indicative of very permeable aquifer material.

Water isotope and microbial indicator samples both support the groundwater travel times estimated by turbidity analysis. Concentrations of *E. coli* in Tafuna wells were most highly correlated with rainfall amounts totaled over a 48 hour window starting 72 hours preceding the sample time. This indicates *E. coli* travels to well pumps within 1 to 3 days after a rain event. Three-week time series $\delta^{18}O$ and $\delta^{2}H$ values in groundwater showed response to rainfall within 48 hours and continued for a number of days. Groundwater isotope compositions were deflected towards the composition of storm event precipitation (Figure 1). Additionally, since water isotopes are a conservative tracer that mixes linearly, a basic isotope mass-balance model (Fry 2006) could be used to estimate the fractions of recently recharged rainfall vs. deep-aquifer groundwater for each sample. Results show that some GUDI wells may pump up to 50% storm event water during or after heavy rain events.

Conclusions

- In the Tafuna well field, the GUDI problem is likely caused by highly permeable aquifer material as opposed to poorly constructed wells.
- Rainfall-event recharge in the Tafuna area travels to well pumps within 18 to 72 hours.
- Water isotopes are a novel and useful tool for validating results of other tracers, and can be used to determine volumetric fractions of groundwater from different sources.

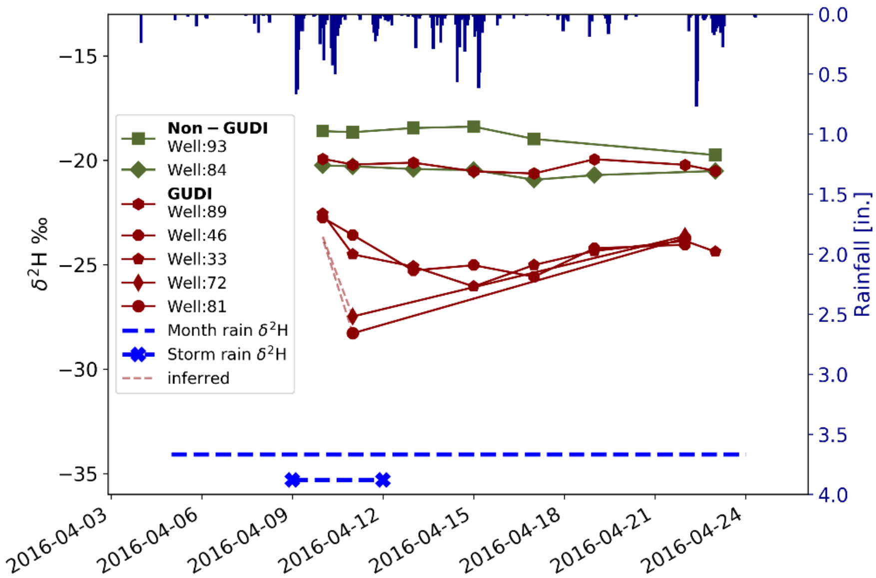

Figure 1. Water isotope values (δ^2H) from groundwater wells (red and green lines) and precipitation (blue solid lines) over a three-week heavy rain-event window. Well samples were taken at a discrete time, whereas precipitation samples represent the volume weighted integration of all rain falling throughout two multi-day collection periods: (1) a 4 day period spanning the initial heavy rain event (blue dashed line with blue **x**), and (2) over the entire month of April (blue dashed line without **x**).

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Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa

Basic Information

Title:	Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa
Project Number:	2017AS472B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Irrigation, Agriculture, Hydrology
Descriptors:	None
Principal Investigators:	Sayed Bateni

Publications

1. Lum, M., S.M. Bateni, J. Shiri, and A. Keshavarzi, 2017, "Estimation of reference evapotranspiration from climatic data, "International Journal of Hydrology, 1(1):00005, DOI: 10.15406/ijh.2017.01.00005.
2. Tajfar, E., S.M. Bateni, P. Gentine, and S. Margulis, 2017, "Estimation of surface turbulent fluxes via variational assimilation of air temperature and specific humidity," Poster presented at 97th American Meteorological Society Meeting, Seattle, WA, January 22-26, 2017.

Abstract

Irrigation is an important issue in American Samoa and has raised concerns for farmers due to the high cost of water. One of the easiest and most affordable ways to protect water resources in American Samoa is to design an optimal irrigation scheduling. In this project, two weather stations were installed in the Malaeimi and Taputimu farms on American Samoa to measure meteorological variables. These meteorological variables were used in the Penman-Monteith equation to estimate reference evapotranspiration. The fractional canopy coverage and root depth were measured for Chinese cabbage and pak choi in the Malaeimi and Taputimu farms. These measurements were sent to Bryta Company in California to incorporate them into the CropManage irrigation software. Incorporating the root depth and canopy coverage fraction measurements as well as evapotranspiration estimates into the CropManage allows farmers on American Samoa to optimally irrigate their farmlands.

Problem and Research Objectives

In some regions of American Samoa, water is by far the major constraint to crop production. Even areas with abundant rainfall experience a high seasonal variability that does not maintain adequate water for the crops throughout the year (Yu et al. 1997). High temperature and evapotranspiration rate, in combination with limited water storage capacity of soil, also reduce water availability for crops (Izuka et al. 2005). On the other hand, the limited supply of water is subject to ever increasing demands. American Samoa (like many other places) is growing in population and it is important to implement water conservation measures to stretch supplies as long as possible. One of the easiest and most effective ways to conserve the water resources in American Samoa is to design an optimal irrigation scheduling.

Our research objective was to develop a robust method (based on the water budget equation) to efficiently schedule irrigation in the farmlands of American Samoa. The irrigation scheduling algorithm uses weather station-derived evapotranspiration, soil water holding capacity, and the application rate of the irrigation system to estimate the appropriate irrigation interval and volume of water to apply in order to maximize growth and minimize losses to leaching.

Methodology

Canopy coverage and root depth data for Chinese cabbage and pak choi are collected in American Samoa. Farm location, start and end dates are shown in Table 1.

Table 1. Farm location, number of cycle, start and end dates of the field and total number of days the crops were in the fields in Malaeimi and Taputimu Villages.

Island	Location	Crop	Number of cycle	Start Date	End Date	Total Days
American Samoa	Malaeimi	Chinese Cabbage (thianchin)	1	09/28/2017	11/2/2017	35
	Malaeimi	Pak Choi (Joi Choi)	1	01/22/2018	02/28/18	37
	Taputimu	Pak Choi (Joi Choi)	2	01/23/2018	02/28/18	37

Figure 1a–c shows planted fields in Malaeimi and Taputimu. Weather stations were installed at Malaeimi and Taputimu locations on American Samoa to record hourly micrometeorological data (wind speed, air temperature, rainfall, incoming solar radiation, and relative humidity). These data will be used in the Penman-Monteith equation to estimate reference evapotranspiration. Figure 2 shows the installed weather stations at Malaeimi and Taputimu locations.

Figure 1a. The Chinese cabbage field in Malaeimi.

Figure 1b. The pak choi field in Malaeimi.

Figure 1c. The pak choi field in Taputimu.

Figure 2a. Weather station set up in Malaeimi Village.

Figure 2b. Weather station set up in Taputimu Village.

Principal Findings and Significance

Fraction of canopy coverage (%) (fc) and root depth (Rd) were measured for 2 different crops, namely Chinese Cabbage, and Pak Choi in Malaeimi and Taputimu (Figure 3).

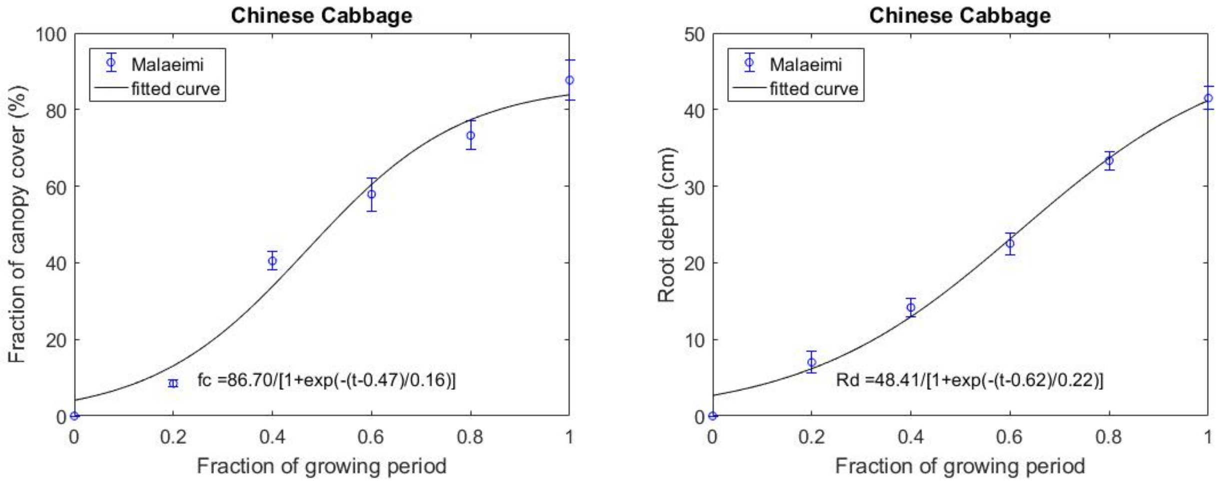

Figure 3. Variations of canopy cover fraction (%) (left column) and root depth (right column) versus fraction of growing period for Chinese cabbage.

Publications Cited in Synopsis

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Assessment of Groundwater Availability in the Volcanic Rock Aquifers of Hawaii-modification

Basic Information

Title:	Assessment of Groundwater Availability in the Volcanic Rock Aquifers of Hawaii-modification
Project Number:	2015HI465S
USGS Grant Number:	G15AC00507
Sponsoring Agency:	U.S. Geological Survey
Start Date:	9/1/2016
End Date:	9/0/2017
Funding Source:	104S
Congressional District:	
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Aly I El-Kadi

Publications

1. Izuka, S.K., J.A. Engott, M. Bassiouni, A.G. Johnson, L.D. Miller, K. Rotzoll, and A. Mair, 2016, "Hawai'i volcanic aquifers—Hydrogeology, water budgets, and conceptual models," USGS Scientific Investigations Report, 2015–5164, 158 p.
2. Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, "Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii," Abstract H31G-1506, presented at 2015 Fall Meeting, AGU, San Francisco, CA, December 14–18.
3. Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, "Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii," The Second Conference on Water Resource Sustainability Issues on Tropical Islands, Honolulu, HI, December 1–3.
4. Izuka, S.K., K. Rotzoll, and T. Nishikawa, 2016, "Challenges of modeling groundwater in the volcanic island aquifers," Poster presented at 2016 U.S. Geological Survey National Groundwater Workshop, Reno, NV, August 29–September 2, 2016.
5. Rotzoll, K., and S.K. Izuka, 2017, "Impacts of groundwater withdrawals in Hawaii," Presented at 2017 Geological Society of America, Cordilleran Section—113th Annual Meeting, Honolulu, HI, May 23–25, 2017.
6. Rotzoll, K., and S.K. Izuka, 2017, "Modeling effects of historical groundwater development on water resources of Hawaii," Presented at 2017 Pacific Water Conference—4th Annual Conference, American Water Works Association, Honolulu, HI, February 14–16, 2017.
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FINAL REPORT

Assessment of Groundwater Availability in the Volcanic-Rock Aquifers of Hawaii

May 2018

Aly I. El-Kadi
Kolja Rotzoll

WRRC-2018-02

Project Number: 2015HI465S

Water Resources Research Center
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Abstract

The availability of fresh groundwater for human use is limited due to the impact of withdrawals that are deemed unacceptable. Quantifying the island-wide hydrologic impacts of withdrawal is thus important to assess fresh groundwater availability. The results of numerical groundwater-flow models of Kauai, Oahu, and Maui simulating historical withdrawals from Hawaii's volcanic aquifers indicated that the types and magnitudes of impacts vary among hydrogeologic settings. In high-permeability freshwater-lens aquifers, saltwater intrusion and reductions in coastal groundwater discharge have been the principal consequences of withdrawals. In dike-impounded groundwater and thickly saturated low-permeability aquifers, reduced groundwater discharge to streams, water-table decline, or reduced flows to adjacent freshwater-lens aquifers can be unacceptable consequences that limit groundwater availability. The models were used to quantify and delineate the spatial distribution of these impacts. The models can also be used to examine how anticipated changes in groundwater recharge and withdrawals will affect groundwater availability in the future.

Problem and Research Objectives

The availability of fresh groundwater for human use is secured provided that the impacts of withdrawals are acceptable by community stakeholders or water-resource managers. Quantifying the island-wide hydrologic impacts of withdrawal is thus important to assess fresh groundwater availability. Such impacts mainly include saltwater intrusion, water-table decline, and reduction of groundwater discharge to streams, nearshore environments, and downgradient groundwater bodies. The scope of work covers numerical modeling of island-wide aquifers utilizing newly available recharge and hydrogeologic information for the islands of Kauai, Oahu, and Maui (Izuka et al. 2016). The objectives are to (1) improve understanding of the most developed regional groundwater-flow systems in the main islands of Hawaii, (2) update knowledge of the availability of groundwater resources, and (3) provide insight into the impacts of human activity and climate change on groundwater resources.

Methodology

Groundwater-flow models of Kauai, Oahu, and Maui were constructed using MODFLOW 2005 with the Seawater-Intrusion Package (SWI2), which simulates the transition between saltwater and freshwater as a sharp interface (Bakker et al. 2013). Consistent model construction, calibration, and analysis were streamlined using Python scripts (Bakker et al. 2016). The models were calibrated to recent conditions (2001–10 average), matching observed water levels, freshwater/saltwater interface depths, and discharge to streams, tunnels, and springs.

Principal Findings and Significance

Results of simulating historical withdrawals from Hawaii's volcanic aquifers show that the types and magnitudes of impacts vary among hydrogeologic settings. In high-permeability freshwater-lens aquifers, saltwater intrusion and reductions in coastal groundwater discharge have been the principal consequences of withdrawals. In dike-impounded groundwater and thickly saturated low-permeability aquifers, reduced groundwater discharge to streams, water-table decline, or reduced flows to adjacent freshwater-lens aquifers can be unacceptable consequences that limit groundwater availability.

Development of the freshwater lens systems in southern Kauai has caused rise of the freshwater/saltwater interface and accounts for most of the island's reduction in submarine groundwater discharge. In contrast, withdrawals in eastern Kauai have caused reduction in stream base flow. Oahu accounts for nearly half of the groundwater withdrawals in Hawaii. Most withdrawals are from the freshwater-lens systems in southern Oahu, where withdrawals have caused the rise of the freshwater/saltwater interface and reductions in spring and submarine discharge. Withdrawal from the dike-impounded systems in Oahu's mountains has caused reductions in stream base flow. Development in central Maui, where the majority of the island's withdrawals occur, has caused the rise of the freshwater/saltwater interface and reduction in coastal discharge. Withdrawals in the center of West Maui Volcano have caused reductions in stream base flow.

In general, simulations showed that the development of Hawaii's groundwater resource has led to regional water-table decline, freshwater/saltwater interface rise (both indicative of reduction in freshwater storage), and reduction of discharge to streams, springs, and the ocean. Quantifying impacts that limit groundwater availability for specific regions can lead to improved groundwater management. The models can also be used to examine how anticipated changes in groundwater recharge and withdrawals will affect groundwater availability in the future.

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Evaluating Student Training and STEM Workforce Development at the National Institutes for Water Resources (NIWR)

Basic Information

Title:	Evaluating Student Training and STEM Workforce Development at the National Institutes for Water Resources (NIWR)
Project Number:	2015HI478S
USGS Grant Number:	G16AC00335
Sponsoring Agency:	INTERIOR, USGS
Start Date:	8/1/2016
End Date:	7/1/2020
Funding Source:	104S
Congressional District:	
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Darren T. Lerner

Publications

1. Brazil, L.E., 2017, “The water resource workforce: Impressions from the nonprofit sector,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
2. Donohue, M.J., E.A. Greene, D.T. Lerner, and P. Moravcik, 2017, “Students, fellows and Feds: Training the next generation of water resource professionals,” Special Session at the University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
3. Donohue, M.J., E.A. Greene, P. Moravcik, and D.T. Lerner, 2017, “Evaluating student training and STEM workforce development at the National Institutes for Water Resources (NIWR),” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
4. Donohue, M.J., D.T. Lerner, and E. Greene, “Student training and workforce development,” A white paper on the U.S. Geological Survey National Institutes for water resources role and capabilities. (in preparation)
5. Greene, E., 2017, “The United States Geological Survey (USGS) workforce: Today and tomorrow,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
6. Lerner, D.T., 2016, “Alumni/workforce development an under-used metric?” Presented at 2016 NIWR Annual Meeting, February 8–10, 2016, The Hotel George, Washington, D.C.
7. Lerner, D.T., 2016, “NIWR human resource tracking effort,” Presented at Sea Grant Association Biannual Meeting, October 8–9, 2016. Newport, RI.

8. Lerner, D.T., and M.J. Donohue, 2017, “NIWR student training & workforce development,” Presented at National Institutes for Water Resources Annual Meeting, February 27–March 1, 2017, Phoenix Park Hotel, Washington, D.C.
9. Snow, E., 2017, “How the USGS engages with universities to provide research and training opportunities for students,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
10. Webb, C., 2017, “How embracing diversity improves results: Sharing experiences from a 20 year career in a water utility,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
11. Brazil, L.E., 2017, “The water resource workforce: Impressions from the nonprofit sector,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
12. Donohue, M.J., E.A. Greene, D.T. Lerner, and P. Moravcik, 2017, “Students, fellows and Feds: Training the next generation of water resource professionals,” Special Session at the University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
13. Donohue, M.J., E.A. Greene, P. Moravcik, and D.T. Lerner, 2017, “Evaluating student training and STEM workforce development at the National Institutes for Water Resources (NIWR),” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
14. Donohue, M.J., D.T. Lerner, and E. Greene, “Student training and workforce development,” A white paper on the U.S. Geological Survey National Institutes for water resources role and capabilities. (in preparation)
15. Greene, E., 2017, “The United States Geological Survey (USGS) workforce: Today and tomorrow,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
16. Lerner, D.T., 2016, “Alumni/workforce development an under-used metric?” Presented at 2016 NIWR Annual Meeting, February 8–10, 2016, The Hotel George, Washington, D.C.
17. Lerner, D.T., 2016, “NIWR human resource tracking effort,” Presented at Sea Grant Association Biannual Meeting, October 8–9, 2016. Newport, RI.
18. Lerner, D.T., and M.J. Donohue, 2017, “NIWR student training & workforce development,” Presented at National Institutes for Water Resources Annual Meeting, February 27–March 1, 2017, Phoenix Park Hotel, Washington, D.C.
19. Snow, E., 2017, “How the USGS engages with universities to provide research and training opportunities for students,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
20. Webb, C., 2017, “How embracing diversity improves results: Sharing experiences from a 20 year career in a water utility,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
21. Donohue, M.J., and D.T. Lerner, “Student training and workforce development at the USGS Water Resources Research Institutes,” Journal of Contemporary Water Research and Education. (in review)

Abstract

Student training and workforce development are key academic, social, and economic metrics. A primary element of the U.S. Water Resources Research Act (WRRA) is the training of the next generation of scientists and engineers through the United States Geological Survey (USGS) and National Institutes for Water Resources (NIWR). The National Institutes for Water Resources has a demonstrated record in this area having trained 25,000 students in its first 50 years while currently supporting or training approximately 1,000 students annually at more than 150 universities, as well as mentoring USGS interns. However, the compilation, analyses, and presentation of these data to better understand and document the USGS and NIWR contributions to education and workforce development have been modest. Further exploration on the workforce placement of students supported by the USGS and NIWR will clarify the value of this investment to society. This research investigates the education and training activities and outcomes of NIWR through the WRRA and the role of these efforts in our nation's science, technology, engineering, and mathematics (STEM) workforce. Findings will inform understanding of USGS and NIWR student support, and the role this support plays in training the next generation of federal water scientists and managers.

Problem and Research Objectives

Student training and workforce development is a key academic, social, and economic metric valued by society including: industry, universities and colleges, the US Congress, the US Office of Management and Budget (OMB), and the United States Geological Survey (USGS), among others.

A major component of the Water Resources Research Act (WRRA) is to provide for training of the next generation of scientists and engineers through the USGS National Institutes for Water Resources (NIWR). The National Institutes for Water Resources has a demonstrated record in this area having trained 25,000 students in its first 50 years while currently supporting or training approximately 1,000 students annually at more than 150 universities, as well as mentoring USGS interns. However, the compilation, analyses and presentation of these data to better understand and document NIWR's contributions to education and workforce development have been modest, to date. Further exploration on the workforce placement of students supported by NIWR will clarify the value of this investment to society.

This research investigates the education and training activities and outcomes of NIWR through the WRRA and the role of these efforts in our nation's science, technology, engineering and mathematics (STEM) workforce. Findings will inform understanding of NIWR's student support, and the role this support plays in training the next generation of federal water scientists and managers.

Research Objectives

A. Evaluate and identify a web-based, user-friendly alumni database for use by state water institute programs and/or NIWR.

B. Identify and rank alumni search strategies.

C. Develop an online-base social science survey instrument to investigate NIWR alumni workforce placement within the USGS.

Methodology

In collaboration with the USGS and NIWR:

(1) A module-based alumni database suitable for use by state water institutes and/or NIWR was identified. Target student data collection included alumni name, year sponsored, degree earned, and current position.

(2) Alumni search strategies were identified and ranked for use by state water institutes and/or NIWR. Search strategies included social media and other online opportunities such as professional memberships, traditional development avenues, and other traditional (e.g., reporting) and non-traditional modalities.

(3) A survey was developed for use by USGS and NIWR to explore the role of WRRA and NIWR in USGS workforce training and development. An appropriate online survey software was used (SurveyMonkey), and questions crafted to investigate: overall knowledge of WRRA and NIWR by USGS personnel; any support of USGS personnel by WRRA funded activities as a student, employee or fellow; length of any support; role of any WRRA support in seeking and/or ability to obtain employment with the USGS; length of employment with the USGS; and other information.

Principal Findings and Significance

A. The module-based alumni database was identified. Recommended data to be included at minimum include: alumni name, year sponsored, degree earned and current position. The parallel development of an update to NIWR.net may confound application.

B. Alumni search strategies were identified in the peer-reviewed journal publication resulting from year 1 project activities.

C. Development of an online-based social science survey instrument to investigate NIWR alumni workforce placement within the USGS was completed and delivered to the USGS.

Proposals or Projects Initiated Based on this Research

Developing Regional Collaboration and Coordination among USGS Water Resources Research Institutes and the NOAA Sea Grant College Programs. A proposal submitted to the USGS by Darren T. Lerner, WRRC Interim Director and Mary J. Donohue, Specialist Faculty, The University of Hawaii Water Resources Research Center and Sea Grant College Program, University of Hawaii at Manoa, Honolulu, HI 96822. (pending)

Joint regional leadership meetings of programs of the NOAA National Sea Grant College Program and the USGS Water Resources Research Act to foster collaboration and enhance services and products provided to constituents. These meetings included directors of state programs in the regions identified as well as national leadership of NOAA and the USGS.

- Pacific Regional Meeting, October 3, 2017, Portland, OR.
- Gulf of Mexico Regional Meeting, February 3–4, 2018, Tuscaloosa, AL.
- Great Lakes Regional Meeting, May 10–11, Ann Arbor, MI.

Additional regional meetings are planned in 2018 and 2019 for the North Atlantic and mid-Atlantic regions of the United States

Understanding the hydrology of a rainforest watershed in Hawaii

Basic Information

Title:	Understanding the hydrology of a rainforest watershed in Hawaii
Project Number:	2016HI459B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Hydrology, Surface Water, Ecology
Descriptors:	None
Principal Investigators:	YinPhan Tsang, Carl Evensen

Publications

1. Huang Y.-F., Tsang, Y.-P., and C. Evensen, “Different approaches of streamflow measurement for rainforest watersheds in Hawaii.” (in preparation)
2. Tsang, Y.-P., A. Strauch, A. Lynch, and D. Infante. 2016. “The natural flow regime of Hawaii streams.” Poster presented in 2016 American Geophysical Union, San Francisco, CA, December 12–16, 2016.
3. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017HI474B** “Understanding the hydrology of a rainforest watershed in Hawaii” by Principal Investigator Yin-Phan Tsang.

Wastewater treatment for point source processing and resuse

Basic Information

Title:	Wastewater treatment for point source processing and resuse
Project Number:	2016HI460B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Engineering
Focus Categories:	Treatment, Wastewater, None
Descriptors:	None
Principal Investigators:	Michael Cooney, Marek Kirs

Publications

1. Teehera, Kim B., S.T. Lin, K.M. Lamichhane, K. Rong, M. Kirs, R. Babcock, M J. Cooney, 2017, “Survivability of Indicator Microorganisms in the High Rate Anaerobic-Aerobic Digester (HRAAD),” Poster presented in 2017 Pacific Water Conference, Honolulu, HI, February 14–16, 2017 (awarded first place).
2. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017HI475B** “Wastewater treatment for point source processing and reuse” by Principal Investigator Michael Cooney.

Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem

Basic Information

Title:	Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem
Project Number:	2016HI461B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Categories:	Water Quality, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Rosanna Alegado

Publications

1. Beebe, Charles, 2018, “Effects of insular mangrove removal on primary productivity within a traditional Hawaiian aquaculture system,” M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Moehlenkamp, Paula, 2018, “Influence of mangrove removal on water budget and pathogens in Heeia Fishpond,” M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
3. Frank, K.L., K.L. Rogers, C.G. Wheat, and R.A. Alegado, 2016, “Linking benthic microbial community dynamics to diel redox variations in a near shore costal environment, Heeia Fishpond,” Poster presented in 2016 American Geophysical Union Fall Conference, San Francisco, CA, December 2016.
4. Nelson, C.E., and R.A. Alegado, “Ridge to reef: Incorporating authentic place-based and community-engaged research experiences into undergraduate environmental science curricula,” Poster presented in 2017 American Society for Limnology and Oceanography Meeting, Honolulu, HI, February 2017.
5. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017HI467B** “Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem” by Principal Investigator Rosanna Alegado.

IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU

Basic Information

Title:	IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU
Project Number:	2016HI462B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Wastewater, Hydrology
Descriptors:	None
Principal Investigators:	Craig R Glenn, Henrieta Dulai

Publications

1. Dores, D., M. Mathioudakis, C. Glenn, R. Whittier, and H. Dulai, 2017, “Identifying pollutant sources along groundwater flowpaths in Kaneohe, Oahu, Hawaii,” in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.
2. Mathioudakis, M., C. Glenn, and D. Dores, 2017, “Examining groundwater and surface water interactions to determine the effects of anthropogenic nutrient loading on stream and coastal water quality,” in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.
3. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017HI466B** "Identifying groundwater flow and contamination to streams: Kahaluu Watershed, Oahu" by Principal Investigator Craig R. Glenn.

Microbial communities and sources of bacteria in Honolulu’s water supply

Basic Information

Title:	Microbial communities and sources of bacteria in Honolulu’s water supply
Project Number:	2016HI463B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Categories:	Groundwater, Water Quality, Water Supply
Descriptors:	None
Principal Investigators:	Marek Kirs

Publications

1. There are no publications for 2016.
2. There are no publications for 2017.

Due to a programming anomaly, two different project numbers were generated for the same project. A progress report for Year 2 can be found at **2017HI476B** “Microbial communities and sources of bacteria in Honolulu’s water supply” by Principal Investigator Marek Kirs.

IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU

Basic Information

Title:	IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU
Project Number:	2017HI466B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Wastewater, Hydrology
Descriptors:	None
Principal Investigators:	Craig R Glenn

Publications

1. Dores, D.E., M.R. Mathioudakis, C.R. Glenn, R.B. Whittier, and H. Dulai, 2017, “Identifying pollutant sources along groundwater flowpaths in Kaneohe, Oahu, Hawaii,” in Geological Society of America Abstracts with Programs, 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, HI, Vol. 49, No. 4. doi: 10.1130/abs/2017CD-293031.
2. Mathioudakis, M.R., C.R. Glenn, and D.E. Dores, 2017, “Examining groundwater and surface water interactions to determine the effects of anthropogenic nutrient loading on stream and coastal water quality,” in Geological Society of America Abstracts with Programs, 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, HI, Vol. 49, No. 4. doi: 10.1130/abs/2017CD-292737.
3. Litchmore, D.T., M.R. Mathioudakis, D.E. Dores, C.R. Glenn, 2017, “UAV drone based thermal infrared imaging to delineate endmember stream discharge behavior,” in Abstract EP31B-1869, 2017 AGU Fall Meeting, December 11–15, 2017, New Orleans, LA.

Abstract

Over 1,000 on-site sewage disposal systems (OSDS; e.g., cesspools, septic tanks) exist throughout the Kahaluu region of the Kaneohe Bay drainage basin, posing significant public health hazards and environmental degradation. Our results importantly show how OSDS leachate within this region differentially impacts specific areas of shallow groundwaters, streams, and Kaneohe Bay shorelines, with OSDS density and subsurface hydrogeologic flowpaths acting as major controls. To locate sources and trace subsurface contaminant flow to these waters, we used unmanned aerial vehicle thermal infrared (UAV-TIR) imaging to map submarine groundwater discharge (SGD), seepage runs to locate groundwater baseflow into streams, and hydrologic modeling to quantify surface and groundwater flow. The stable isotopic composition of nitrate ($\delta^{15}N_{nitrate}$), documents locations of wastewater leachate in groundwaters, streams and ocean, while nutrients, common ions, and other tracers further quantify specific sources and variations in contaminant flow. Aqueous carbonate geochemistry quantifies extent of denitrification and definitive differentiation of OSDS contamination to receiving waters.

Problem and Research Objectives

The risk that sewage effluent released to the environment poses to human health and the environment is well documented. On-site sewage disposal systems (OSDS) are a substantial threat to groundwater quality (Giblin and Gaines 1990, Richardson et al. 2016) and the second most frequently reported cause of contaminated groundwater in the United States (USEPA 2007), as high system density or improper function can lead to contamination of aquifers and adjacent surface waters by nutrients and pathogens (Beal et al. 2005). Hawaii has nearly 88,000 cesspools that leach approximately 53 million gallons per day of raw sewage into the State's groundwater and surface waters (HDOH 2017). The Kahaluu region, which drains into Kaneohe Bay, is one of the state's most significant areas of concern (HDOH 2017), as over 1,000 OSDS are located within this 34 km² area (Whittier and El-Kadi 2009). While some surface contamination may originate as OSDS overflow during storm events, there is also chronic introduction of sewage contamination by direct OSDS discharge to groundwater, which is then laterally transmitted to streams and/or the ocean. This project thus assesses the presence of OSDS leachate in the groundwater and streams of the Kahaluu watersheds and Kaneohe Bay, and develops a comprehensive groundwater model to quantify trajectories and fluxes of wastewater-borne nutrients and other contaminants.

Methodology

To catalogue regional hydrology, confirm model accuracy, and ensure opportunistic sampling, unmanned aerial vehicle thermal infrared (UAV-TIR) imaging was utilized to map locations of groundwater inputs into the ocean (as submarine groundwater discharge [SGD]) and into streams (as baseflow). TIR data were calibrated to real-time in situ thermistors and further validated by temperature and salinity surveys following flights. New methods for post-processing of UAV-TIR data were developed, from which the first TIR maps of submarine groundwater discharge into Kaneohe Bay have been produced.

As a supplemental assessment of stream hydrology, long-term stream gauges were installed in the primary streams of the study area, Waihee and Kahaluu, recording stream level and temperature every 15 minutes. Volumetric discharge measurements were made at each gauging station with a FlowTracker Doppler device to establish a mathematical relationship between stream level and stream discharge (i.e., rating curve). Paired with active upstream USGS gauging stations, our downstream stations acted as anchor points for stream-seepage runs. Two seepage runs (wet and dry season) were completed for each stream to delineate reaches that gain groundwater; segments identified as gaining were sampled to include a new collaborative source-tracking study (including a robust suite of pharmaceutical and wastewater compounds) initiated between this project and the Hawaii Department of Health (HDOH) and U.S. Geological Survey (USGS).

Dissolved nutrient concentrations were obtained from streams, coastal springs, groundwater wells, and porewater to determine the extent of nutrient pollution. $\delta^{15}N$ and $\delta^{18}O$ of nitrate were used to differentiate natural, agricultural, and wastewater inputs of nitrate (Kendall and McDonnell, 1998; Liu et al. 2006; Kendall et al., 2007; Xue et al. 2009). To account for denitrification, dissolved common ion concentrations and the isotopic composition of boron are used as biologically conservative tracers to supplement these results. Aqueous carbonate geochemistry was further analyzed for each groundwater and porewater sample to quantify the extent of denitrification.

A steady-state MODFLOW groundwater model of the entire Kaneohe Bay watershed was completed, and subsurface OSDS contaminant transport was simulated via the MT3DMS package. A more localized model is currently in development, which utilizes all field data (e.g., stream discharge rates, TIR data, soil porosity) for calibration or verification purposes, and simulates subsurface contaminant transport in Kahaluu in fine resolution.

Principal Findings and Significance

Results indicated that increases in OSDS leachate occur in all five streams of the study area as a varying function of OSDS density and subsurface geology. Preliminary groundwater contaminant transport models have been completed, and new localized models are in development to provide a tool for remediation scenarios. Our UAV-TIR maps revealed diffuse coastal SGD with nine point-sourced SGD plume locations based on thermal anomalies and corresponding salinity anomalies, and stream gages and seepage runs have identified the discrete stretches of streams where groundwater enters as baseflow. TIR and salinity data reveal that a greater magnitude of groundwater was discharging from the alluvial sediments of the northernmost watersheds than from the dike-intruded basalt of the southernmost watersheds. This is a significant concern, as most OSDS are located within the shallow alluvial sediments of the northern watersheds. Dissolved inorganic nitrate and common ion concentrations were systematically higher in the Kahaluu and Waihee streams than in the other three watersheds, which is directly correlative with their higher OSDS densities. $\delta^{15}N$ and $\delta^{18}O$ of nitrate corroborated these results and indicated the source of nitrate was dominantly wastewater. Ongoing efforts to quantify the effect of denitrification on $\delta^{15}N$ values showed increased $\delta^{15}N$ values for nitrate in oxygen-depleted shallow groundwater. This is opposed to the minimal denitrification observed in deep, well-oxygenated groundwater that does not alter the diagnostic $\delta^{15}N$ signature. At the coast, elevated nitrate concentrations and elevated $\delta^{15}N$ values in beachface porewaters and in estuarine and coastal waters indicative of OSDS leachate were present at the locations we identified and mapped as sourcing significant discharge plumes of SGD. These coastal locations need further study as they may prove to be the most efficient and direct conduits for land-based effluent to reach the sensitive near-shore coral reef ecosystems of Kaneohe Bay.

Proposals or Projects Initiated Based on this Research

Collaborative Investigation of Hydraulic and Geochemical Connectivity Between Wastewaters and Other Land Uses and the Ocean Waters of Waialua Bay, Oahu. NOAA Sea Grant College Program. Craig Glenn (P.I.), Project Period: 2/2018–7/2020.

Publications Cited in Synopsis

Beal, C.D., E.A. Gardner, and N.W. Menzies. 2005. "Process, performance, and pollution potential: A review of septic tank–soil absorption systems," Australian Journal of Soil Research 43(7):781–802.

Giblin, A.E., and A.G. Gaines. 1990. "Nitrogen inputs to a marine embayment: The importance of groundwater," Biogeochemistry, 10(3):309–328.

Hawaii State Department of Health (HDOH). 2017. Relating cesspools and prioritization for replacement. Report to the Twenty-ninth Legislature State of Hawaiʻi, 2018 Regular Session, 24 p plus appendices.

Kendall, C., E.M. Elliott, and S.D. Wankel. 2007. Tracing anthropogenic inputs of nitrogen to ecosystems, in Stable Isotopes in Ecology and Environmental Science: Blackwell Publishing Ltd, Oxford, UK, p. 375–449.

Kendall, C., and J.J. McDonnell. 1998. Tracing nitrogen sources and cycling in catchments, in Isotope Tracers in Catchment Hydrology: Amsterdam, Elsevier Science B.V., p. 519-576.

Lapointe, B.E., J.D. O'Connell, and G.S. Garrett. 1990. "Nutrient couplings between on-site sewage disposal systems, groundwaters, and nearshore surface waters of the Florida Keys," Biogeochemistry 10(3):289–307.

Liu, C.Q., S.L. S.L., Y.C. Lang, and H.Y. Xiao. 2006. Using δ15N- $\delta^{18}O$- values to identify nitrate sources in karst ground water, Guiyang, Southwest China. Environmental Science and Technology 40: 6928–6933.

Richardson, C.M., H. Dulai, and R.B. Whittier. 2017. Sources and spatial variability of groundwater-derived nutrients in Maunalua Bay, Oʻahu, Hawaiʻi: Journal of Hydrology: Regional Studies, 16 p. http://dx.doi.org/10.1016/j.ejrh.2015.11.006.

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Whittier, R.B., and A.I. El-Kadi. 2009. Human health and environmental risk ranking of onsite sewage disposal systems: Final Report, prepared for the State of Hawaii Department of Health.

Xue, D., J. Botte, B. De Baets, F. Accoe, A. Nestler, P. Taylor, O. Van Cleemput, M. Berglund, and P. Boeckx. 2009. Present limitations and future prospects of stable isotope methods for nitrate source identification in surface- and groundwater: Water Research 43: 1159–1170. DOI: 10.1016/j.watres.2008.12.048.

Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem

Basic Information

Title:	Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem
Project Number:	2017HI467B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Categories:	Water Quality, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Rosanna Alegado

Publications

1. Beebe, C., 2018, “Effects of insular mangrove removal on primary productivity within a traditional Hawaiian aquaculture system,” M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Moehlenkamp, P., 2018, “Influence of mangrove removal on water budget and pathogens in Heeia Fishpond,” M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
3. Frank, K., M. Branco, W.H. Thomas, R.A. Alegado, “Influence of physical and anthropogenic forcing on microbial community dynamics in a subtropical estuarine system,” Poster presented at 2017 International Choanoflagellate Workshop, Berkeley, CA, June 2017.
4. Moehlenkamp, P., C.A. Beebe, and R.A. Alegado, “Water dynamics of Heeia fishpond,” Poster presented at 7th International Conference on ecological futures: Humans and island environments, Honolulu, HI, April 2018.

Abstract

Temperate estuaries have served as systems for studying the influences of climate change on the coastal environment (Cooper and Brush 1993, De Carlo et al. 2007, Officer et al. 1984, Ringuet and Mackenzie 2005), however, few tropical estuarine systems have been thoroughly examined. Our goal was to link microbial community dynamics and function over physical and chemical gradients, in order to identify environmental conditions that are predictive of the microbial community succession following extreme climate events. Such studies may constrain the biogeochemical cycles favored as climate regimes shift. In this study, we analyzed the role of stochastic climate events (e.g., storms) on a water column microbial community structure by sampling a network of stations within the Heeia Coastal Ocean Observing System, every month over a 24-month period, to describe natural changes in microbial community structure (abundance, diversity, and composition) as a function of seasonable variability and environmental drivers.

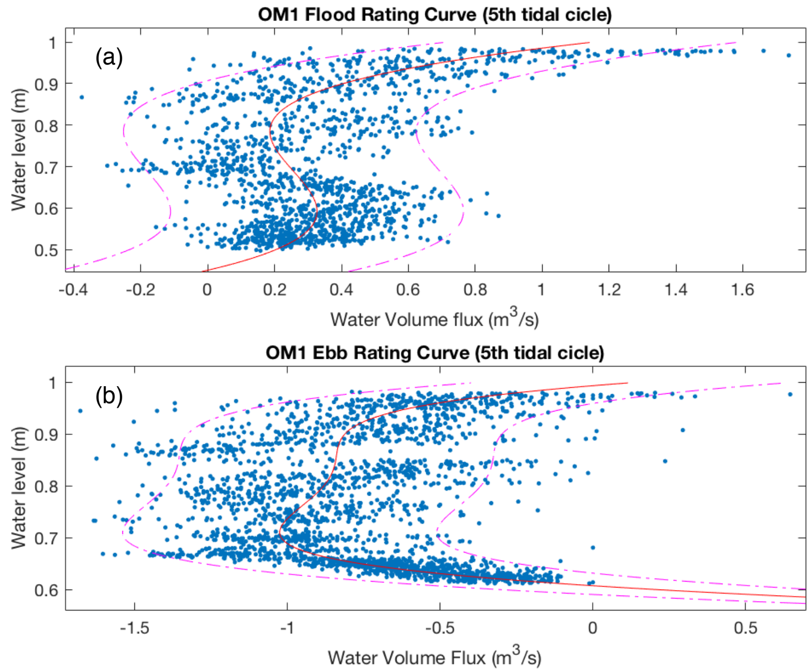
Problem and Research Objectives

Although a number of temperate estuaries have served as systems for studying the influences of climate change on the coastal environment (Cooper and Brush 1993, De Carlo et al. 2007, Officer et al. 1984, Ringuet and Mackenzie 2005), few cognate systems have been thoroughly examined in tropical estuarine environments. Estuaries constitute some of the most geochemically active ecosystems on the planet, and the effects of climate change may be enhanced in these environments due to human activity (Chu 1995, Day et al. 2008, Scavia et al. 2002). Our goal is to link microbial community dynamics and function over physical and chemical gradients in order to identify environmental conditions that are predictive of the microbial community succession following extreme climate events. Such studies may constrain the biogeochemical cycles favored as climate regimes shift.

The objective of this proposal is to analyze the role of stochastic climate events (e.g., storms) on water column microbial community structure by sampling a network of stations within the Heeia Coastal Ocean Observing System (HCOOS), every week over a 24-month period, to describe natural changes in microbial community structure (abundance, diversity, and composition) as a function of seasonable variability and environmental drivers.

Methodology

In the second year of the grant, we quantified the volume of water ($m^3 s^{-1}$) moving into and out of each makaha (sluice gate) over extended periods of time by deploying a Nortek current meter for seven days in each of the six fishpond makaha. The resulting flow and water level data were used to create rating curves (water level [m] vs. water flow [$m^3 s^{-1}$]) for each makaha (Figure 1). As rating curves relate water level to water volume flux, they allow for the future monitoring of water volume flow through the makaha to be accomplished by monitoring water level with less expensive pressure sensors alone. Resulting rating curves provide an insight into fishpond circulation, residence time, and the relative importance of each makaha for water exchange. Using size-fractionated seawater, the contribution of particles to biological



Note: Red line = curve fit to the data, pink line = 95% confidence interval.
Figure 1. Rating curves for (a) flood and (b) ebb tides at Ocean makaha 1 (OM1).

activity will also be evaluated. A multi-parameter water quality monitor sonde (YSI 6600 v2; YSI Incorporated, Yellow Springs, OH) was used to obtain *in situ* profiles of the temperature, salinity, and pH. Nutrients (i.e., nitrate, nitrite, ammonia, phosphate, and silica) were analyzed through the SOEST Laboratory for Analytical Biogeochemistry (S-LAB).

At each station, approximately 1.5 L of bulk seawater was collected from a depth of 30 cm via a Teflon-lined Niskin bottle (General Oceanics Inc., Miami FL) and used for the DNA-based analysis of the microbial community structure, flow cytometric enumeration of planktonic cells, and quantification of macronutrients. Genetic material from size-fractionated microbial communities was extracted from the surface water column as previously performed (Gobet et al. 2012, Yeo et al. 2013). Next generation Illumina "pyrotag" sequencing (Kozich et al. 2013) was used to generate extensive sequencing datasets of 16S and 18S rRNA data to simultaneously characterize diversity in all three domains of life represented in the HFP over the course of the 18 months. These experiments revealed the contribution of water quality to the particle-attached microbial assemblage, the bulk biological processes, and the response of this community to environmental perturbations. Comparative phylogenetic analysis has the potential to provide significant insight into the environmental drivers of naturally occurring genomic variability and distribution of microbial genes and biochemical mechanisms and higher-order community organization and dynamics within tropical coastal ecosystems. Baseline measurements for fecal contamination were taken before and during mangrove island clear-cutting (which began in Fall 2017). Water samples (1 L) were filtered onto a 0.4 µm PES filter and frozen dry at -20°C until genomic DNA could be extracted using MoBio PowerSoil® DNA Isolation Kits (MoBio 12888). Quantitative polymerase chain reaction (qPCR) assays were used to quantify human and bird fecal contamination by targeting specific subgroups of bacteroidales associated with animal sources of fecal contamination: birds and humans. In addition, we specifically assessed the presence and abundance of cattle egrets, the main residents of the mangrove island by targeting *Enterococcus* associated with gull fecal contamination (Green et al. 2012) and an *Helicobacter* species associated with general bird fecal contamination (Green et al. 2012).

Principle Findings and Significance

Comparison of the 2017 collected flux data with the 2012 data indicated dramatic differences in the water budget as a result of the Ocean Break repair. Before 2015, the submerged elbow wall at Ocean Break created a confined system. The 2017 data suggest that as a result of replacing the submerged elbow wall with a new makaha, the previously confined system changed to tidally driven system. In general, the flow velocities were higher compared to 2012, which suggested a more overall water volume was circulated and exchanged, and had a considerable decrease in residence time. As in 2012, the two northern most ocean makaha still seemed to dominate the majority of the water exchange. We are currently in the process of calculating the exact number for the water flux and residence time.

Four different assays amplified on the DNA extracted from a cattle egret feces sample collected on the mangrove island in the Summer of 2017. We are currently testing the DNA extracted from our water samples on selected qPCR assays for source tracking of human and bird microbial contamination.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Beebe, C.B., and R.A. Alegado, "Water dynamics of Heeia fishpond," Oral presentation in 7th International Conference on Ecological Futures: Humans and Island Environments, Honolulu, HI, April 2018.

Heeia Fishpond Mangrove Removal and Water Quality Improvement. Hawaii State Department of Health, Clean Water Branch. Maya Walton (P.I.), and R. Alegado (Co-P.I.), Project Period: 03/01/2017–02/28/2019.

McCoy, D., M.A. McManus, K. Kotubetey, A.H. Kawelo, C. Young, E.K. Bennett, B. D'Andrea, K.C. Ruttenberg, R.A. Alegado, "Large-scale climatic effects on traditional Hawaiian fishpond aquaculture," Oral presentation in Hawaii Sea Grant–Japan Conference, Honolulu, HI, September 2017.

Understanding and Adapting to Environmental Change in Native Hawaiian Aquaculture Systems. NOAA FY18 Saltonstall-Kennedy Competition. R. Alegado (P.I.), C. Smith (P.I.), and E. Franklin (P.I.), Project Period: 9/01/2018–8/31/2020.

Water Budget and Pathogen Dynamics in Heeia Fishpond During Restoration Regimes. NOAA Sea Grant College Program NA09OAR4170060. M. McManus (P.I.), and R. Alegado (Co-P.I.), Project Period: 01/01/2017–12/31/2017.

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Understanding the hydrology of a rainforest watershed in Hawaii

Basic Information

Title:	Understanding the hydrology of a rainforest watershed in Hawaii
Project Number:	2017HI474B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Hydrology, Surface Water, Ecology
Descriptors:	None
Principal Investigators:	YinPhan Tsang

Publications

1. Huang Y.-F., Y.-P., Tsang, and C. Evensen, “Different approaches of streamflow measurement for rainforest watersheds in Hawaii.” (in preparation)
2. Huang, Y.-F., and Y.-F. Tsang, 2017, “Apply spatially distributed rainfall data to a hydrological model in a tropical watershed in Hawaii,” Poster presented at 2017 American Geophysical Union Fall Meeting, New Orleans, LA, December 11–15, 2017.

Abstract

The objective of year two of this project was to study the temporal and spatial resolution of meteorological data for the proposed hydrological model by addressing the rainfall-runoff process in the rainforest watershed. Last year (year one of the project), in addition to the stream gage, a weather station at Lyon Arboretum was established to provide frequent meteorological data. This station will provide meteorological data at the much needed temporal resolution to address the fast-response of rainfall-runoff process in the rainforest watershed. In addition, we applied different spatial resolutions of meteorological input to the Soil and Water Assessment Tool (SWAT) to assess the model performance. The results showed that the model with a higher spatial resolution of meteorological input predicted the streamflow better. This result was presented at the 2017 American Geophysical Union fall meeting. The next step is to apply the higher temporal and spatial resolution of meteorological data to address the rainfall-runoff process in the rainforest watershed.

Problem and Research Objectives

To further our understanding of the hydrology in a rainforest watershed, we established the monitoring system at the selected rainforest watershed located in Manoa, Oahu. We continued measuring the streamflow to strengthen the rating curve, and install the real-time weather station along with the established real-time stream gage. The objectives of this study are to:

1. Install continuous stream monitoring stations at Aihualama Stream, which flows through the watershed at Lyon Arboretum, and
2. Build a hydrological model with streamflow data to describe the hydrology of the rainforest watershed.

Methodology

Install the Weather Station to Pair with Streamflow Monitoring

In the monitored Aihualama Stream, the streamflow showed fast response to the rainfall, usually within minutes. After the first year of this project, we realized that the available rainfall data (i.e., daily rainfall) is not in the temporal resolution needed (i.e., hourly or shorter) to address the fast responding rainfall-runoff process in the select rainforest watershed. A portion of the second year funding received in August 2017 was used to establish a weather station at the Lyon Arboretum. This was supported by Dr. Carl Evensen (Co-Principal Investigator) and Dr. Rakan Zahawi (Director, Lyon Arboretum). Dr. Thomas Giambelluca (Hydroclimatologist) was consulted for the site selection of weather monitoring, and his research technician, Mike Nullet, assisted with the installation of the weather station on February 16 and 20, 2018 (Figures 1 and 2). The goal is to install the weather station to report hourly data with the UH Wi-Fi connection, and to provide complete meteorological data, including temperature, humidity, rainfall, solar radiation, and soil moisture. Currently, we are in the process of testing the data acquisition while continuously measuring the stream discharge at the stream gauge that was established in the first year, and building the rating curve (Figure 3).

Figure 1. Research technician Mike Nullet, stream biologist Cory Yap, and student Brendan Martin installing the weather station at Lyon Arboretum.

Figure 2. Weather station measuring temperature, humidity, wind, rainfall, and soil moisture at Lyon Arboretum.

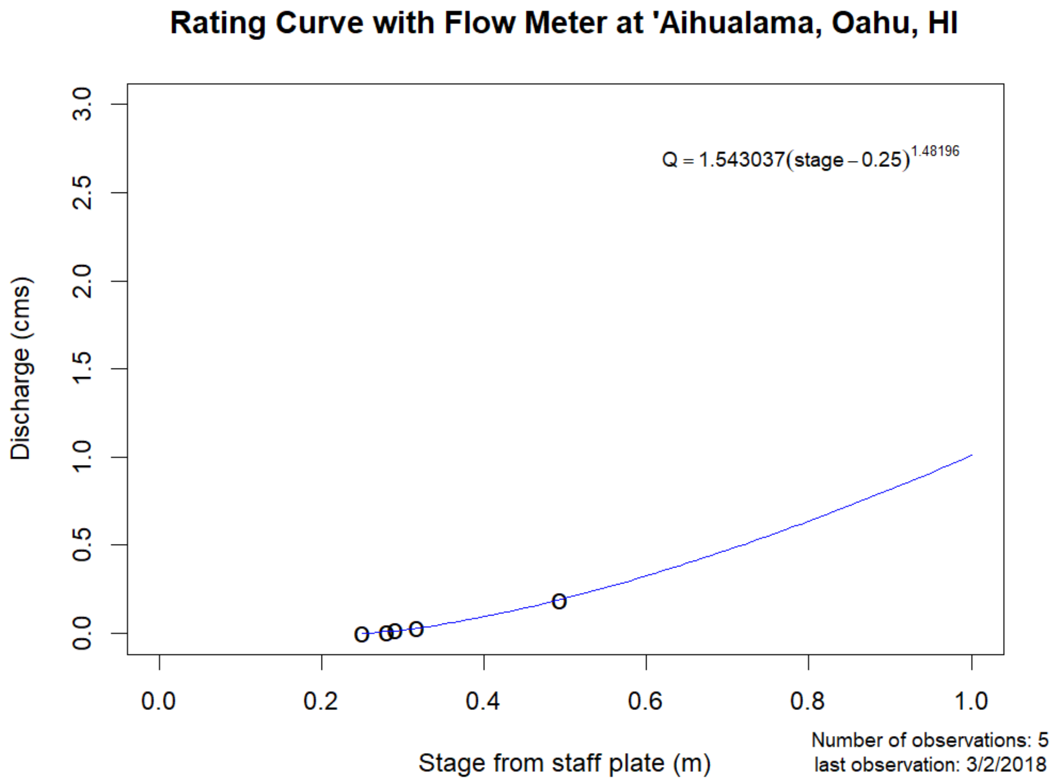


Figure 3. Rating curve for the Aihualama upstream, Oahu, Hawaii.

Hydrological Modeling – SWAT

As proposed, the SWAT model was applied to simulate the rainfall-runoff process. Specifically, this year, the streamflow simulation was assessed with input with different spatial representation of meteorological data. Point observation of rainfall and temperature data was obtained, as well as 250-m resolution grids of rainfall and temperature data. The simulation was compared with three scenarios: (1) point rainfall and temperature, (2) subbasin-averaged rainfall with point temperature, and (3) subbasin-averaged rainfall and temperature.

Principal Findings and Significance

The SWAT model was able to better simulate streamflow when using the subbasin-averaged daily rainfall and temperature (Table 1, Scenario 3). Both coefficient of determination (R^2) and Nash–Sutcliffe model efficiency coefficient (NS) showed that the modeling results were significantly improved from point to spatially-distributed rainfall and temperature. The next step is to develop a hydrological model that uses a gridded rainfall rather than a subbasin-averaged rainfall.

Table 1. SWAT model performance of three scenarios in calibration and validation.

	Scenario	R^2	NS
Calibration	1	0.60, 0.12, NA	0.38, -0.10, NA
	2	0.45, 0.67, NA	0.41, 0.59, NA
	3	0.47, 0.66, NA	0.43, 0.58, NA
Validation	1	0.43, 0.14, 0.16	0.08, -0.44, -0.22
	2	0.48, 0.60, 0.94	0.42, 0.38, -0.17
	3	0.53, 0.62, 0.94	0.43, 0.40, 0.40

Note: R^2 = Coefficient of determination, NS = Nash–Sutcliffe model efficiency coefficient. The three numbers under R^2 and NS are values for three U.S. Geological Survey stream gauges16248500, 16240500, and 16241600, respectively. Scenario 1 is point meteorological input; Scenario 2 is subbasin-average rainfall with point temperature, and Scenario 3 is subbasin-average rainfall and temperature.

Wastewater treatment for point source processing and resuse

Basic Information

Title:	Wastewater treatment for point source processing and resuse
Project Number:	2017HI475B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Engineering
Focus Categories:	Treatment, Wastewater, None
Descriptors:	None
Principal Investigators:	Michael Cooney

Publications

1. Lin, S.T., K.M. Lamichhane, K.B. Teehera, K. Rong, M. Kirs, R. Babcock, and M.J. Cooney, 2018, “Anaerobic-aerobic biofilm digestion of chemical contaminants and pathogen indicators in synthetic wastewater,” Poster presented in 2018 Pacific Water Conference, Honolulu, HI, February 7–8, 2018.
2. Lin, S.T., K.M. Lamichhane, K.B. Teehera, K. Rong, M. Kirs, R. Babcock, and M.J. Cooney, 2018, “Anaerobic-aerobic biofilm—Based digestion of contaminants of emerging concern (CEC) in synthetic wastewater,” Poster presented at 2017 CTAHR and COE Student Research Symposium, University of Hawaii at Manoa, Honolulu, HI, April 7, 2018.
3. Teehera, K.B., S.T. Lin, K.M. Lamichhane, K. Rong, M. Kirs, R. Babcock, M J. Cooney, 2017, “Survivability of indicator microorganisms in the high rate anaerobic-aerobic digester (HRAAD),” Poster presented at 2017 Pacific Water Conference, Honolulu, HI, February 14–16, 2017.

Abstract

Many chemical contaminants and enteric pathogens commonly found in wastewater pose health threats to humans even at low concentrations. While major pathogen concentrations are subject to EPA regulations, research to eliminate or reduce the concentration of chemical contaminants of emerging concern (CEC) in wastewater effluents is increasing. In this study, the efficacy of a biofilm based anaerobic-aerobic treatment process to reduce liquid phase concentrations of select chemical CEC as well as key pathogen indicator organisms from wastewater has been investigated. With respect to CEC, the removal efficiency of caffeine (CAE), carbamazepine (CBZ), and three estrogens was investigated. With respect to fecal pathogen indicators, the systems impact on concentrations of *Escherichia coli* (CN-13) and F+ specific coliphage (MS-2 bacteriophage) was investigated and was used as reactor feed. The CEC were spiked into the reactor feed (synthetic wastewater solution developed by the Organization for Economic Co-operation and Development (OECD) to overall concentrations of 500 µg/L. The system showed no observable reduction in CBZ over a 51-day evaluation period while after 74 days, CAE showed an 11.09% reduction in effluent from the anaerobic digester (AD) stage and a 91.90% reduction in the effluent from the trickling filter (TF). With respect to the estrogens, 17β-estradiol (E2) and 17α-ethinylestradiol (EE2) were spiked and their concentrations (including the E2 degradation byproduct—estrone E1) were monitored. After 90-days of observation, combined concentrations of E1 and E2 showed virtually no reduction in the AD but a 99.67% reduction in the TF; while EE2 showed a 1.62% reduction in the AD stage and 20.36% after the TF stage. These results suggest the combined anaerobic-aerobic biofilm-based reactor system is capable of treating wastewaters highly concentrated with caffeine, estrone, and 17β-estradiol but less so with those contaminated with CBZ and 17α-ethinylestradiol. In analogous experiments, the indicating pathogens *E. coli* CN-13 and F+ specific coliphage (MS-2 bacteriophage) were spiked in the wastewater feed to overall concentrations of 1×10^8 MPN/L and 1×10^6 PFU/L, respectively. Across the overall reactor system, *E. coli* (CN-13) achieved an average of 3-log reductions and F+ Specific Coliphage (MS-2 bacteriophage) achieved an average of 1-log reduction.

Problem and Research Objectives

Water limited island communities, such as those in Hawaii, face mounting demands on their water supply. These demands may include increasing consumption, decreasing rainfall, decreasing groundwater recharge, and the redirection of rainfall over natural watersheds—all of which can stress a pre-existing ground supply of potable water. To protect the existing fresh water supply, there is a viable alternative: recycled water for activities with less stringent standards (e.g., landscaping and agricultural irrigation). Contaminants found in wastewater, which include pharmaceuticals and enteric bacteria, pose a health threat to humans at low doses and the U.S. Environmental Protection Agency (EPA) requires a reduction of pollutant pathogens in treated wastewater before it can be safely reused for secondary purposes. Thus, developing a more cost-effective and low-energy method to reduce both chemical CEC and fecal pathogen (from human and animal sources) concentrations in treated water would be extremely advantageous for both the water reuse industry and small- and medium-sized businesses with the potential to use recycled water (R2).

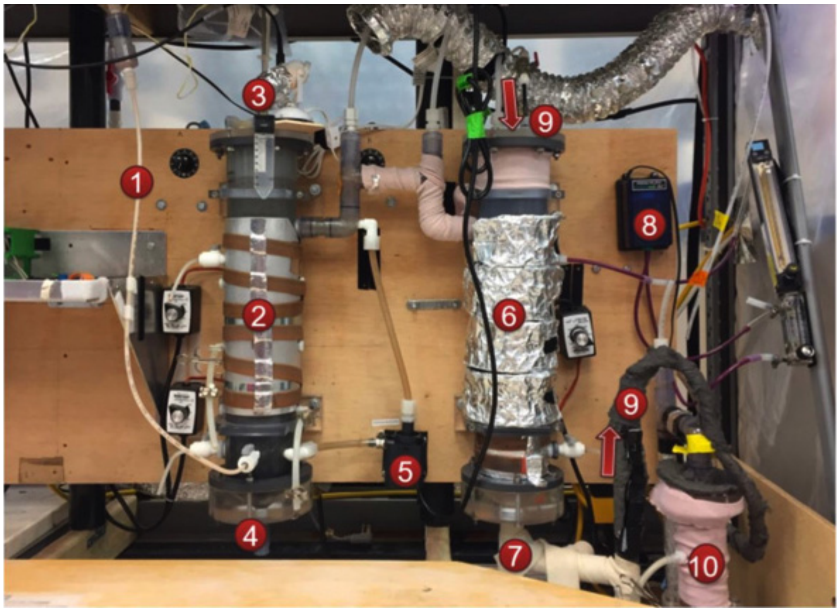
Our hypothesis is that biofilms serve as a natural biological matrix that entraps both micropollutants and pathogenic organisms. This entrapment occurs through sorption processes and can reduce the liquid phase concentrations of both contaminants in receiving waters. Biochar packed biofilm-based reactors also have the potential to accelerate the death and/or biodegradation of enteric organisms and chemical contaminants. Biochar as bioreactor media has been proven to harbor robust biofilms with diverse groups of organisms (Cooney et al. 2016). These biofilms with diverse groups of microorganisms (Khatoon et al. 2014), are more resilient to process disturbances (Andreottola et al. 2000).

The objective of this study is to demonstrate the efficacy of low-energy low-chemical biofilm anaerobic-aerobic reactor systems to realize the efficient degradation of select CEC and enteric pathogens. The project evaluates the reduction of five CEC and the survivability of the indicator organisms through different stages in a biofilm-based high rate anaerobic-aerobic digestion (HRAAD) reactor system. To achieve this, synthetic wastewater was spiked with CAE, CBZ, E2, and EE2 and inoculated with *E. coli* CN-13 and F+ specific ribonucleic acid (RNA) coliphage, bacteriophage MS-2 at concentrations mimicking their concentrations in sewage. The chemical contaminants selected for monitoring in this study are either common chemicals frequently found in wastewater treatment plants or are compounds included in the fourth Contaminant Candidate List (CCL4) published by the EPA (2016), which are anticipated to occur in public water systems but are not currently subject to drinking water regulations. The two microbes monitored are recognized as indicator organisms for fecal contamination and recommended by the EPA to evaluate the safety of drinking and recreational waters.

Methodology

The HRAAD system was comprised of a biochar packed flow anaerobic reactor (AnPB), a biochar packed aerobic TF, and a clarifier or settling tank (ST) all connected in the series (Figure 1). The ST was followed by an overflow filter bay and a final water holding tank (recycle reservoir, RR). The feed (simulated sewage) loaded onto the AnPB reactor flowed over to sequential successive unit operations (i.e., TF, ST, filter bay, and RR) by gravity. The water in the RR was recycled through an external UV light for final polishing (i.e., to remove any residual pathogens in the effluent). The main steps included were:

- Prepared simulated OECD (peptone) sewage.
- Prepared stock solutions of chemical CEC: A stock solution of CAE and CBZ was prepared at 500 mg/L and a separate stock solution of the estrogens was prepared at 1 g/L.
- CEC spiking: The 500 mg/L CAE and CBZ stock solution was added at a 1:1 ratio of mL of stock solution to L of synthetic wastewater feed to achieve an overall concentration of 500 μg/L caffeine and carbamazepine per liter of wastewater feed. The 1 g/L E2 and EE2 stock solution was added at a 1:2 ratio of mL of stock solution to L of synthetic wastewater feed to synthetic wastewater feed fed to achieve an overall concentration of 500 μg/L E2 and EE2 per liter of wastewater feed.
- Collected liquid phase samples (10–15 mL) for pharmaceutical analysis (after spiking) once every hydraulic residence time (HRT), from the feed tank, AD effluent, TF effluent, and ST



NOTE: 1) feed dosing line, 2) biochar packed up-flow AnPB reactor, 3) flow transfer line, 4) solids discharge, 5) AnPB internal recycle pump, 6) biochar packed TF, 7) TF effluent line, 8) TF air pump, 9) TF recycle line, and 10) ST.

Figure 1. High rate anaerobic aerobic digester system.

effluent. Filtered samples with 0.22 µm syringe filters into HPLC vials and storage in a refrigerator (4°C) to maintain integrity of samples.

- Analyzed collected samples with ultra-high-performance liquid chromatography (UHPLC, Thermo Scientific Ultimate 3000) system using a modified method of a study published by D'Alessio et al. (2015).
- Inoculated the reactor with a one-time EE2 dose of 1.6 mL (to achieve an overall concentration of 775 µg/L) to simulate a sudden one-time "surge" of this chemical.
- Measured background (pre-inoculation) concentrations of indicator organisms (*E. coli* CN-13, surrogate for bacteria, and F+ specific coliphages MS-2 [hereafter referred to as bacteriophage MS-2], surrogate for viruses) present in the reactor system inclusive of synthetic feed, anaerobic digester column, aerobic trickling filter column, and clarifier column.
- Prepared seed stocks of *E. coli* CN-13 and bacteriophages MS-2, determine organism densities, and evaluate seed stability during storage (seed stocks stored frozen at -80 °C).
- Spiked synthetic feed with seed stocks of indicator organisms to maintain stable and accurate populations of *E. coli* CN-13 and bacteriophages MS-2 at concentrations 1×10^8 MPN L^{-1} and 1×10^6 PFU L^{-1}, respectively, to mimic the concentrations generally present in raw sewage entering wastewater treatment plants.
- Collected liquid phase samples (30–40 mL) for pathogen indicator organism analysis (after spiking) every 3–4 HRT, from the feed tank, AD effluent, TF effluent, and ST effluent.
- Enumerated (quantified) both indicator organisms (*E. coli* CN-13 and bacteriophages MS-2) in liquid phase (effluent) samples collected from different stages of the HRAAD reactor

system (anaerobic, aerobic, and clarification) and evaluate the efficiency of the HRAAD system in reducing these indicator organisms in each of the reactor stage and in the system overall.

Principal Findings and Significance

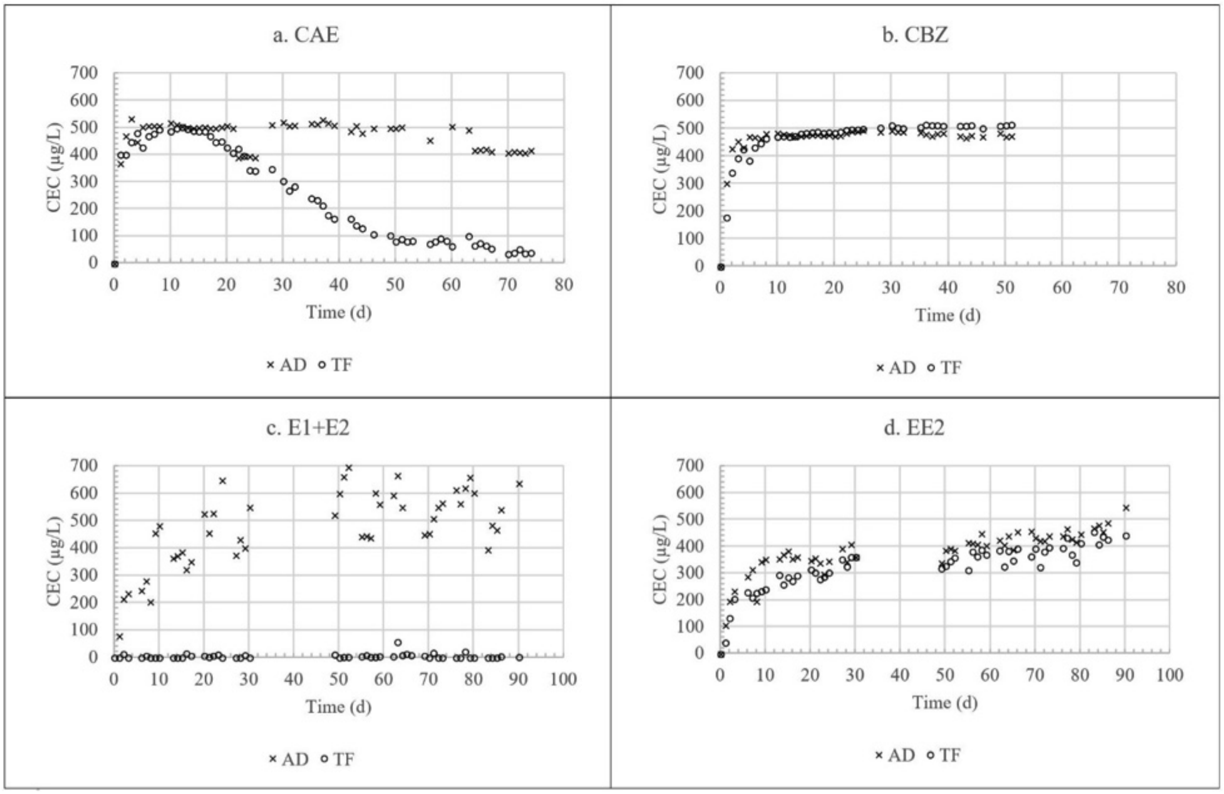
Chemical CEC

Caffeine concentrations leaving the AD initially spiked until quickly leveling off at 500 μg/l until dropping 11.09% in the last few days of analysis (Figure 2a). By contrast, caffeine concentrations leaving the TF dropped consistently over the 74-day evaluation period, eventually removing up to 91.90% (Figure 3a). Carbamazepine was not degraded in either the AD or TF even after its cessation in the feed after 51 days (Figure 3b).

17β-estradiol and 17α-ethinylestradiol were spiked over 90 days and monitored over 149 days. Both 17β-estradiol and estrone concentrations were monitored simultaneously since 17β-estradiol has been cited to degrade into estrone under anaerobic conditions (Gonzalez-Gil et al. 2016). Because E1 was not spiked into the system, its appearance was as a byproduct of E2 degradation. In general, E1 and E2 was not degraded in the AD reactor yet almost entirely degraded in the TF (Figure 3c). Specifically, after 90 days of observation, 17β-estradiol showed no significant reduction in the AD stage and a 99.67% reduction in the TF stage (Figure 3c). The low to non-detectable concentrations of combined E1 and E2 in the TF stage indicate aerobic biofilms are effective at removing both E1 and E2 from the liquid phase.

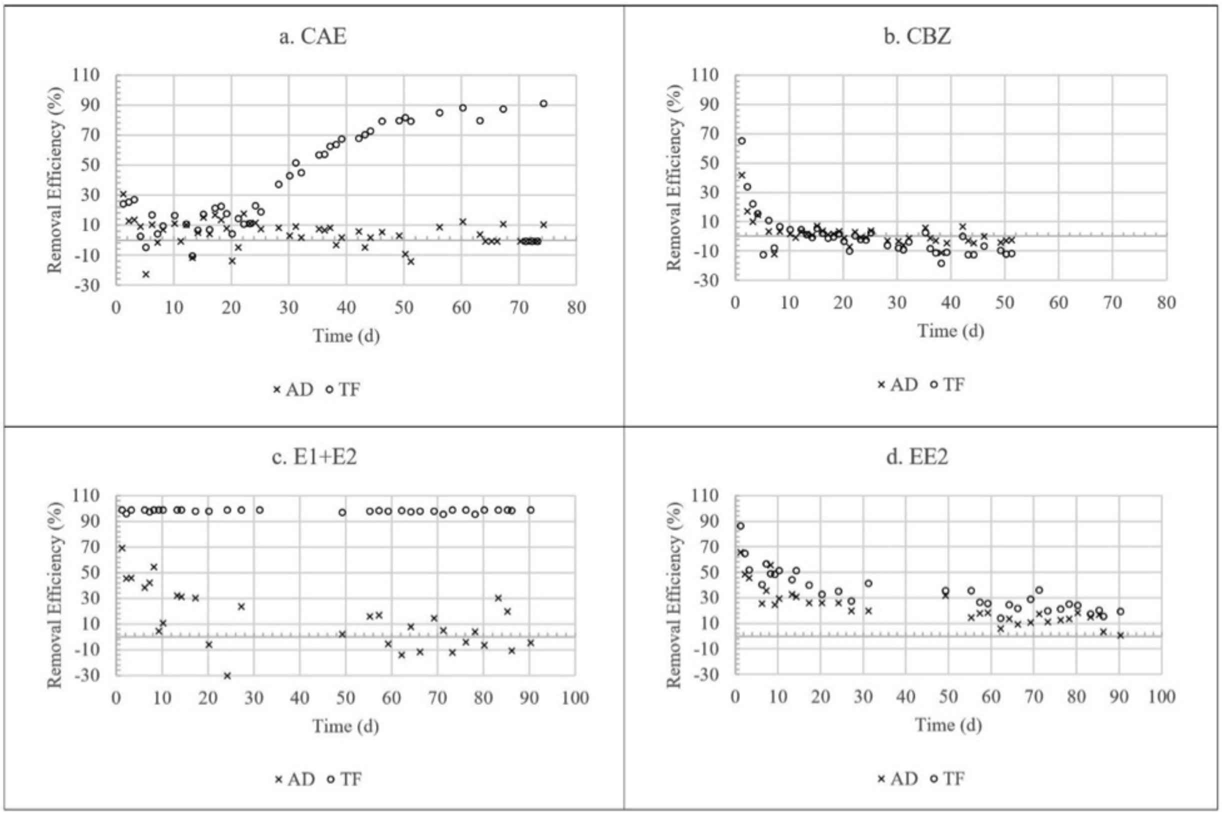
EE2 concentrations recovered after the initial spike were low and slowly increased in both effluents throughout the study. Specifically, concentrations of 17α-ethinylestradiol increased to around 400–500 μL in both the AD and TF stages (Figure 3d). This suggests that initial removal of EE2 from the liquid phase is likely through sorption processes, and with a saturation of biofilm sorption eventually achieved. More EE2 is likely not aggressively biodegraded by anaerobic or aerobic biofilms, with EE2 showing only a 1.62% reduction in the AD and a 20.36% in the TF (Figure 3d).

The abrupt spike of EE2 in the wastewater feed (Figure 4) showed that the system was able to significantly buffer the sudden surges in concentration of this pharmaceutical. This result suggests that even in those cases where a problematic CEC is not readily degraded by anaerobic or aerobic organisms, the utility of biofilm-based reactors is that the biofilms can serve as a sorption medium that absorbs high “surge” concentrations of problematic CEC, significantly tempering their concentrations in the effluent, perhaps to levels that would otherwise trigger regulatory alarms.



NOTE: AD = anaerobic digester, and TF = trickling filter.

Figure 2. Concentration of a) CAE, b) CBZ, c) E1, E2, and d) EE2 measured over time in AD and TF effluents.



NOTE: AD = anaerobic digester, and TF = trickling filter.

Figure 3. Percent removal efficiencies of a) CAE, b) CBZ, c) E1, E2, and d) EE2 over time in AD and TF effluents.

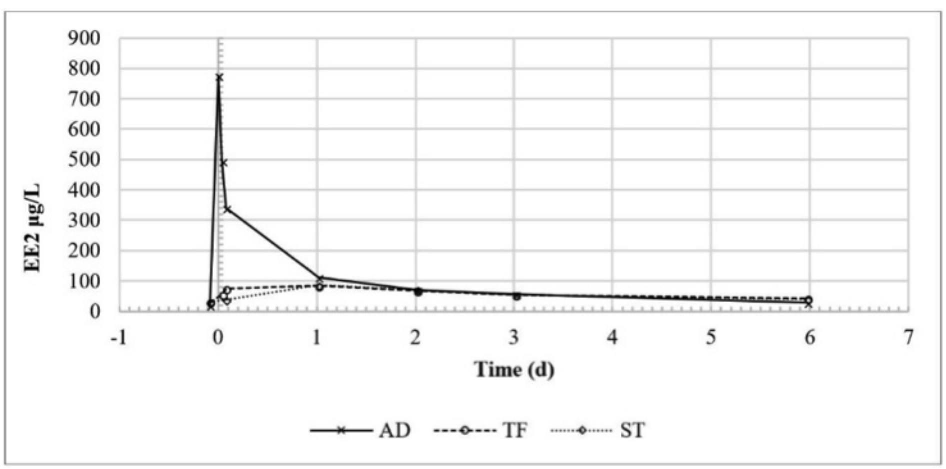
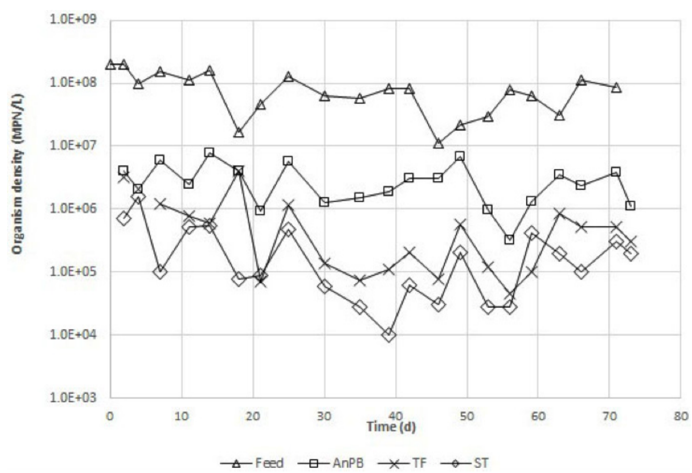


Figure 4. Effluent concentrations of EE2 over a week to analyze efficacy of reactor system to buffer a high load of EE2.

Pathogen Indicator Organisms

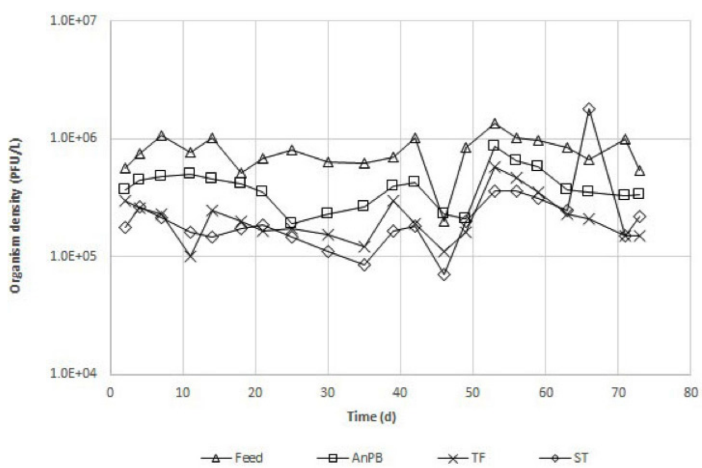
The HRAAD system was loaded with simulated sewage spiked with indicator organisms and the performance monitored for 73 days. On average, one log reduction of *E. coli* and 0.5 log reduction of bacteriophage MS-2 was achieved across the AnPB. Overall, the HRAAD system was able to achieve approximately three log reductions of *E. coli* CN-13 and almost one log reduction of bacteriophage MS-2. The system performance in reducing indicator organisms, (i.e., *E. coli* CN-13 and bacteriophage MS-2) over time across HRAAD system components is presented in Figures 5 and 6, respectively.

The background concentrations (before inoculation) of indicator organisms in liquid phase samples were nominal compared to the concentrations of these organisms maintained in the feed. The *E. coli* CN-13 concentrations for the feed tank, AnPB, TF, and ST were less than 10 MPN/L, 5483 MPN/L, 181 MPN/L, and 52 MPN/L, respectively. The bacteriophage MS-2 was not detected in the system.



NOTE: AnPB = anaerobic digester, TF = trickling filter, and ST = settling tank.

Figure 5. Log reduction of *E. coli* CN-13 over time across HRAAD system components.



NOTE: AnPB = anaerobic digester, TF = trickling filter, and ST = settling tank.

Figure 6. Log reduction of bacteriophage MS-2 over time across HRAAD system components.

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Microbial communities and sources of bacteria in Honolulu’s water supply

Basic Information

Title:	Microbial communities and sources of bacteria in Honolulu’s water supply
Project Number:	2017HI476B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Categories:	Groundwater, Water Quality, Water Supply
Descriptors:	None
Principal Investigators:	Marek Kirs

Publication

1. Kirs M., V. Kisand, C. Nelson, T. Dudoit, P. Moravcik, “Hidden bacterial diversity in Hawaiian aquifers,” The ISME Journal. (in preparation)

Abstract

Currently, we don't know what microbes reside in Hawaii aquifers, hence we are unable to identify impacts to, nor recovery of, the compromised aquifers based on microbiological data. This is a concern as impact from population growth, climate change, and other hazards cannot be measured and evaluated. The overarching goal of the project is to provide the first in depth characterization of the microbial communities and sources of microbes in Honolulu's water supply. The analyses of 37 source water samples and 17 distribution water samples indicated the water quality in Honolulu is generally good. Six of those source water (16%) and one distribution water sample (1%) were positive for total coliforms, while no *Escherichia coli*, *Clostridium perfringens*, F+ coliphages, or sewage specific markers were detected in any of the water samples analyzed. Oahu's groundwater forms a very distinct microbiome that harbors structurally and functionally diverse bacterial communities, which rivals the bacterial diversity found in Oahu's soils.

Problem and Research Objectives

Issue I. No information on microbes living in Hawaii aquifers. A literature search on "microbial communities," "groundwater," and "Hawaii" reveals no relevant related peer-reviewed articles. Without previous data on ambient microbial communities in Hawaii's groundwater we are unable to identify impacts to, nor recovery of, the compromised aquifers based on microbiological data. Climate change is projected to increase risk to people, assets, economies, and ecosystems (IPCC 2014). Extreme weather events, such as tropical storms and hurricanes, are projected to increase in frequency and intensity in the Pacific. It is well established that shifts in rainfall driven by climate change are anticipated to affect watershed processes (Coffey et al. 2014, Strauch et al. 2014), which will probably affect the supply and quality of groundwater. Recent modeling efforts indicate that shifts in rainfall and increased urbanization alter inputs of fecal indicator bacteria in tropical watersheds (Strauch et al. 2014) as well as distribution of environmental pathogens (Coffey et al. 2014, Urquhart et al. 2014), however the impact is not well understood.

Issue II. Hawaii's drinking water supply is also vulnerable to biological and chemical sabotage (Fujioka et al. 2006). This vulnerability is a definite concern as the current political climate is probably the most volatile since the cold war. Terrorist attacks targeting our water supply could affect its microbiology. Currently, we don't know what microbes live in our groundwater as the technologies available to study microbial communities have been inadequate. Therefore, there is a lack of information on what a typical microbiological background in our drinking water supply consists of, ergo we are not able to detect changes when an aquifer has been compromised.

Issue III. Contamination of groundwater with direct surface water input. This situation is another critical issue for some Pacific Islands (Hawaii, American Samoa, and others). Total coliforms and *Escherichia coli*, routinely assayed for in drinking water quality monitoring programs world-wide, are not reliable indicators of fecal contamination as both groups are widespread in tropical soils where they grow at ambient temperatures (Hardina and Fujioka 1991, Byappanahalli et al. 2012). Hence, when these indicator bacteria are detected in source water, it must be determined whether they are truly of fecal origin or if they were leached from soils and sediments with rainfall. If the source of indicator bacteria is soil, it is expected to be of no or low risk to human health, while contamination with human sewage is of greater concern. Most importantly, effective remediation strategies can be applied to mitigate the impact to the water supply when the source of contaminants is identified.

The overarching goal of this project is to characterize microbial communities and sources of microbes in Honolulu's water supply. Consequently the nature of the project is the microbiological analyses of our water supply. This is the first in-depth analysis (checklist) of microbes in our water supply that combines cultivation based and molecular approaches. The two main objectives are (1) identify the microbial community structure in our drinking water system (source water and distribution system); and (2) determine the source of the indicator bacteria (e.g., sewage, soil, or biofilm), if found, in well and tunnel water samples.

Methodology

During the first year of the project (03/01/16–02/28/17), 36 source water samples and 36 soil samples were collected. Source water samples were collected from 27 wells and nine tunnel water ports owned and selected by the Honolulu Board of Water Supply (BWS). The sample locations were selected to represent a variety of Oahu aquifers used by the BWS as drinking water sources. However, the actual wells and tunnel water outlets selected by the BWS were based on the monitoring data, which found the indicator organisms present.

Sampling was conducted in conjunction with the routine sampling program schedule established by the BWS, but no BWS resources were utilized to complete this study. For those reasons, time at each collection site was very limited, and it was not possible to collect samples using in-situ ultrafiltration, which involves a one-hour filtration process at each site and additional setup/take down time.

Samples were collected from 15 July 2016 to 29 December 2016 from the groundwater wells (n = 28), tunnels (n = 7) and shafts (n = 2) (Figure 1) and from July 2 to July 27 from 17 drinking water taps. Typically, we were granted access to one to three wells or tunnels on each collection date. Eight liters of source water were collected for microbial community analyses. An additional one liter of source water samples were collected at each location for the analysis of cultivable microorganism (i.e., total coliforms, *E. coli, Clostridium perfringens*, and F+ specific coliphages) and molecular sewage-specific markers (i.e., human-associated *Bacteroides* and human polyomaviruses). At each well, soil sample (30 ml soil core) was also collected. Water samples were collected at each site from a flamed sampling port and transported on ice to the Water Resources Research Center laboratory. The laboratory samples were filtered onto sterile hydrophilic polyethersulfone membrane filters (Supor®200, 0.2 µm pore size; Pall Corp., Ann Arbor, MI) and stored at -80°C. After completion of the sample collection, the bacterial DNA was extracted from the filters using the PowerSoil® DNA Isolation Kit (MO BIO Laboratories, Inc.; Carlsbad, CA) according to the manufacturer's protocol, with two minutes of bead beating at maximum speed on a Mini Beadbeater™ (Biospec Products Inc;. Bartlesville, OK). All DNA samples were recovered into a 100 µl elution buffer and stored at -80°C. Total coliform, *E. coli*, *C. perfringens*, F+ specific coliphages, and the molecular sewage-specific marker concentrations were determined as described earlier (Kirs et al. 2017). Microbial community structure was determined for soil and source water samples using partial 16S RNA gene amplicon sequencing on MiSeq (Illumina).

Distribution water samples did not yield sufficient amount of DNA for the analyses. Library preparation and sequencing using PE300 chemistry was performed by the Advanced Studies in Genomics, Proteomics and Bioinformatics (ASGPB) facility at the University of Hawaii. Statistical analyses of sequence data is ongoing.

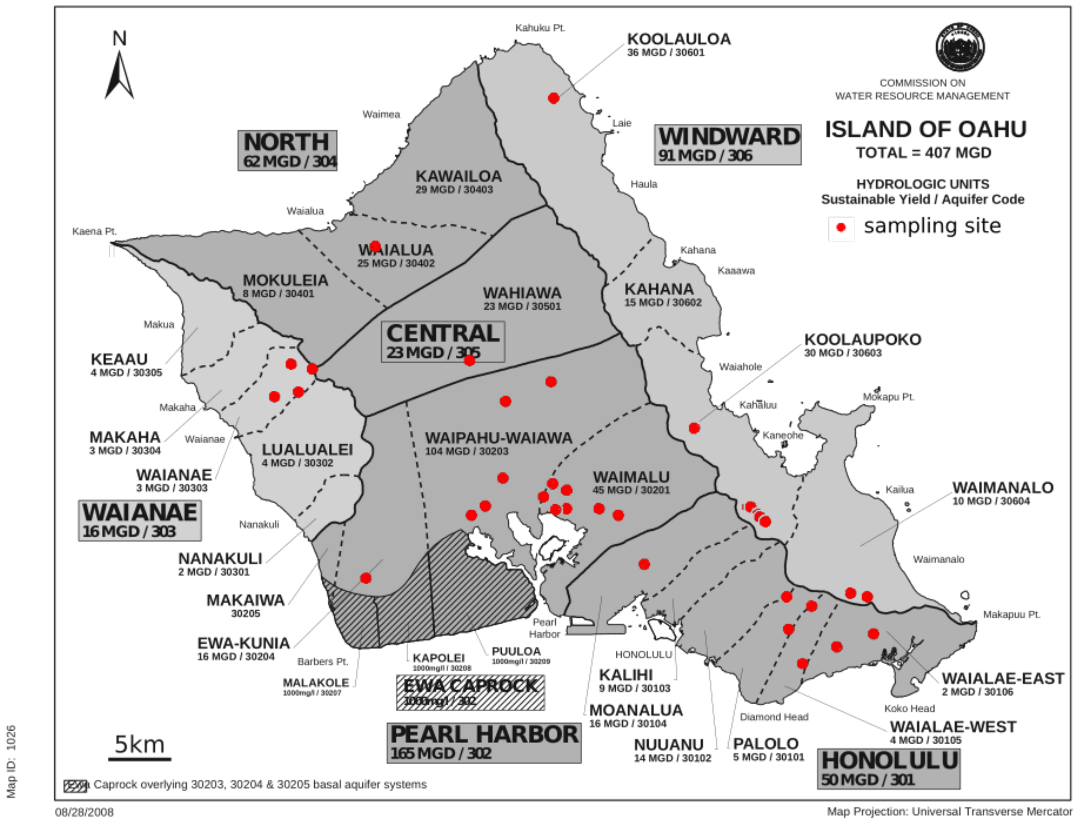

Figure 1. Source water collection sites.

Principal Findings and Significance

Source Water Samples

Six of the 37 groundwater samples (16.2%) were positive for total coliforms, indicating that some of the sources are affected by microbial contaminants. Nevertheless, no *E. coli* or *C. perfringens* were detected in any of the water samples analyzed. No sewage-specific markers (human-associated *Bacteroides*, human polyomavirues), or coliphages were detected in any of the source water samples.

Distribution Water Samples

One out of the 17 tap water samples (5.8%) were positive for total coliforms. Repeat sample was from the same tap was not positive. No *E. coli* or *C. perfringens* were detected in any of the tap water samples analyzed. No sewage-specific markers (human-associated *Bacteroides*, human polyomavirues), or coliphages were detected in any of the tap water samples.

Soil Samples

All soil samples were positive for total coliforms and enterococci. Geometric mean concentrations of both organisms were 450 MPN/g and 22 MPN/g, respectively; but frequently exceeded >2,419.6 MPN/g of soil (64% and 8% samples, respectively). *E. coli* was detected in 55% of the samples, and the concentrations varied from <1 to >2,419.6 MPN/g (geometric mean = 13 MPN/g). *C. perfringens* was detected in 39% of the soil samples (geometric mean = 50 CFU/g) and the concentrations ranged from <1 to 620 CFU/g.

Bacterial Communities in Oahu's Source Water

In collaboration with Tartu University (Dr. Kisand's group), our analyses of over 3.1 million sequences revealed that Oahu's groundwater harbors structurally and functionally diverse bacterial communities (Figure 2), diversity of which is comparable to the microbial communities found in Oahu's soils (Table 1). While the diversity is comparable by both sample types, the source water biome is very different from those found in soils and in human fecal samples (envfit: $R^2 = 0.41$, $P < 0.001$). Only 12.5% operational taxonomic units (OTU) where shared by the soil and source water samples, and 0.7% by human and source water samples. Only 0.47% of OTUs (128) were shared by all sample types (Figure 3). Several bacterial phyla (Acetothermia, Omnitrophica, Parcubacteria, Peregrinibacteria) were associated with source water samples and were not detected in any or only in few soil samples at low levels. Chemoautotrophs were important in source water samples, where nitrifying bacteria accounted for at least 12.5% of sequences identified. Iron oxidizers (>4.3%) and bacteria capable to fix nitrogen were also abundant in source water samples. The analyses of data to determine factors contributing to the distribution of source water bacteria is ongoing.

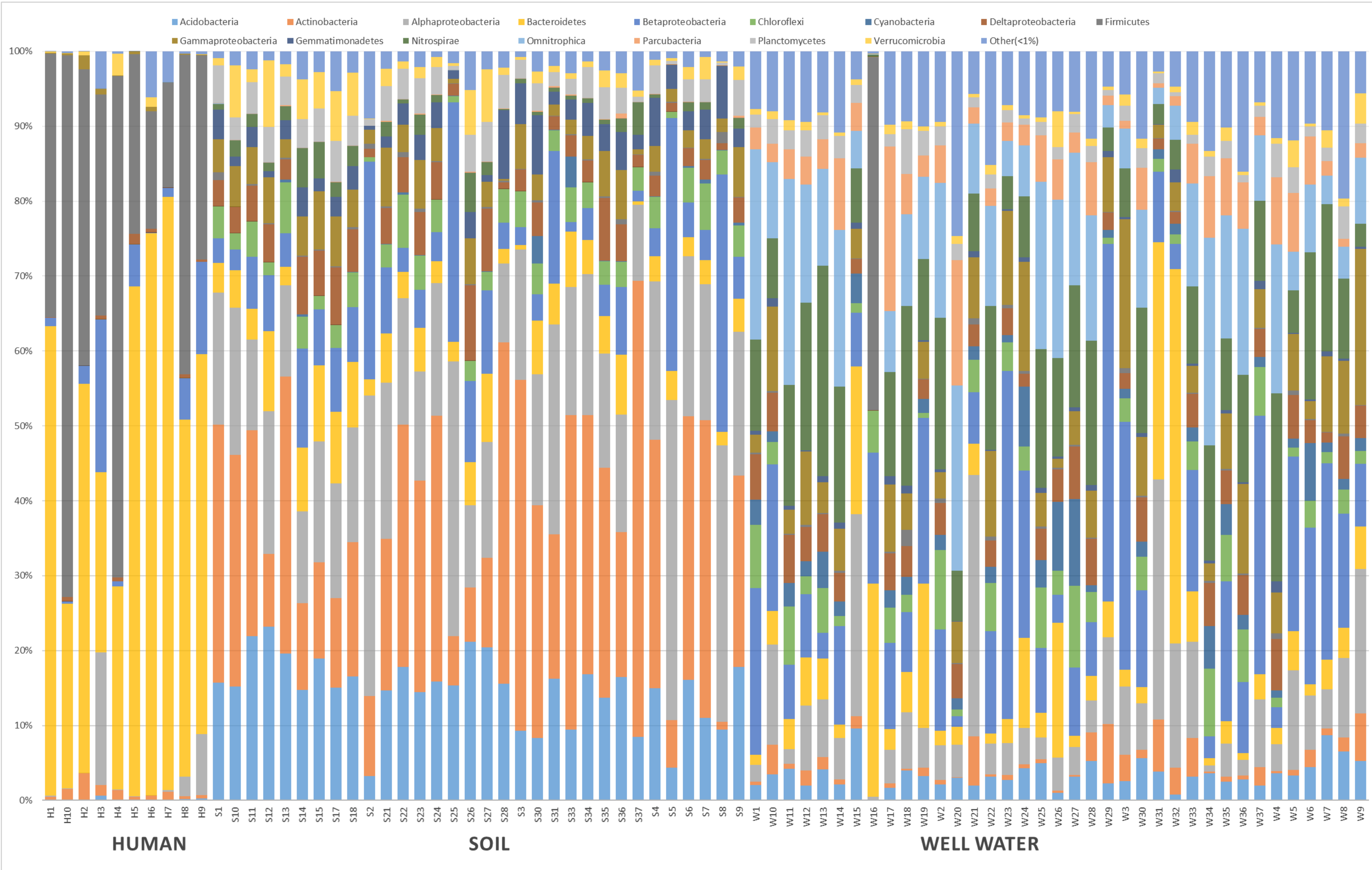

Figure 2. Distribution of bacterial phyla and classes of Proteobacteria in different sample types.

Table 1. Average bacterial abundance, evenness, and diversity in different sample types.

Sample	Abundance (n)	Diversity				Evenness (J)
		Shannon	Simpson	Inverted Simpson	Fisher α	
Human	209	3.04	0.88	11.4	28.1	0.57
Soil	2397	5.98	0.97	209.5	571.6	0.78
Source water	2071	5.37	0.97	70.6	468.9	0.71

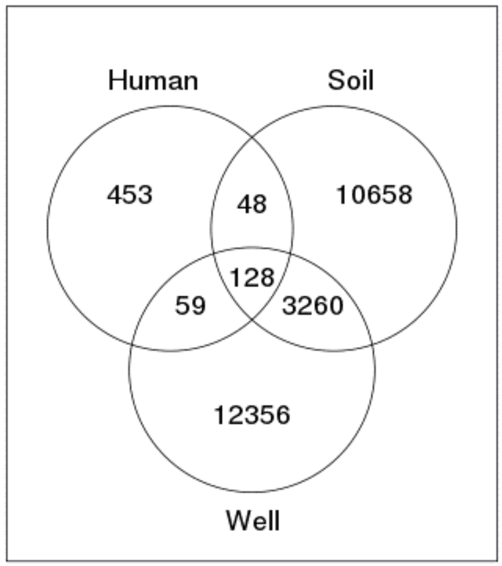

Figure 3. Number of shared operational taxonomic units (clustered at 97% sequence similarity) between different sample types.

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Information Transfer Program Introduction

The goal of the information transform program at the University of Hawaii Water Resource Research Center is to ensure the research reaches the appropriate people. To support that goal, during the FY2017 reporting period, the Center disseminated the information through its web site, seminar series, newsletters and publications; reported our research findings at local and national conferences; and participated in school STEM and science fairs. The Center provided support for the preparation and presentation of peer-reviewed journal articles, proceedings, poster sessions, and project completion reports. Our research is available to the Hawaii State Department of Health, Hawaii Department of Land and Natural Resources, county water supply departments, as well as national regulatory and planning agencies.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016AS458B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	1st
Research Category:	Not Applicable
Focus Categories:	Education, None, None
Descriptors:	None
Principal Investigators:	Philip Moravcik

Publications

1. Kirs, M., V. Kisand, M. Wong, R.A. Caffaro-Filho, P. Moravcik, V.J. Harwood, B. Yoneyama, and R.S. Fujioka, 2017, “Multiple lines of evidence to identify sewage as the cause of water quality impairment in an urbanized tropical watershed,” Water Research, 116:23–33.
2. Kirs, M., P. Moravcik, P. Gyawali, K. Hamilton, V. Kisand, I. Gurr, C. Shuler, and W. Ahmed, 2017, “Rainwater harvesting in American Samoa: Current practices and indicative health risks,” Environmental Science and Pollution Research, pp. 1–9, doi:10.1007/s11356-017-8858-z.
3. There are no publications for 2017.

Introduction

In 2013, Hawaii's Water Resources Research Center (WRRC) was assigned an added responsibility as the WRRIP Center for American Samoa. American Samoa faces a number of water management issues—both drinking and environmental. In order to effectively address these issues, a degree of understanding and familiarity with the problems stakeholders experience is necessary. An advisory council was created in 2016 to help guide and direct WRRC for future research in American Samoa. WRRC faculty have engaged in a number of research projects in American Samoa, some of which are ongoing. The results of these studies will be disseminated to American Samoa stakeholders as they become available.

Problem and Research Objectives

The problems that the ongoing technology transfer effort seeks to mitigate are several; there is a lack of scientific and policy knowledge concerning water issues among American Samoa's general populace. American Samoa has a number of pressing water challenges including provision of (1) adequate clean, freshwater to a population that is spread widely (decentralized) around the main island of Tutuila, (2) proper collection, (3) treatment and disposal of wastewater from these same widespread communities, (4) protection of surface water resources in the face of intensive land use, and (5) protection of nearshore marine resources from contamination borne by discharges from the land. The technology transfer effort of WRRC in American Samoa seeks to disseminate the findings of research projects that attempt to address these concerns.

Researchers from WRRC who are working on several studies in American Samoa have engaged the participation and collaboration of local stakeholders from the American Samoa Community College (ASCC), American Samoa Environmental Protection Agency (ASEPA), the American Samoa Power Authority (ASPA), and the American Samoan National Association of State Departments of Agriculture (NASDA).

Technology Transfer Office Activities

During FY2017, Technology Transfer activities for American Samoa included personal communication with members of the Advisory Committee, assisting with the online proposal system set up, participating in the process to select reviewers for the American Samoa 104B grants, and participating in the review process for the awarding of the grants. The Advisory Committee was invited to provide input into the review process for the 104B proposals.

American Samoa Advisory Committee Members

- Kelley L. Anderson Tagarino, Extension Faculty, American Samoa Community College/ University of Hawaii Sea Grant
- Utu Abe Malae, Executive Director, American Samoa Power Authority
- Peter Gurr, Deputy Director, American Samoa Department of Agriculture

- Hideyo Hattori, American Samoa Management Liaison, Coral Reef Conservation Program and Coastal Zone Management Program, National Oceanic and Atmospheric Administration Program
- Mark Schmaedick, Entomologist, American Samoa Community College
- Tim Bodell, American Samoa Environmental Protection Agency

3rd Conference on Water Resource Sustainability Issues on Tropical Islands

Basic Information

Title:	3rd Conference on Water Resource Sustainability Issues on Tropical Islands
Project Number:	2017AS469B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Categories:	Water Supply, Management and Planning, Climatological Processes
Descriptors:	None
Principal Investigators:	Darren T. Lerner

Publication

1. There are no publications for 2017.

Island states are faced with a unique set of environmental and cultural issues pertinent to the management of water resources. Fresh water resources are under threat on many islands both from overuse and contamination. Ocean waters in these tropical regions are ecologically sensitive and valuable, and similarly threatened by pollution. On some islands, sea level rise is degrading groundwater resources.

Island states are heavily dependent on importing essentials such as food, fuel, and manufactured goods to satisfy their resource needs. On most of these islands, population growth is putting increasing pressure on water resources. It is imperative that these threats to the welfare of the island communities be addressed by sound scientific research before they reach crisis proportions. Sustainable management and protection of island water supplies is even more critical than it is on the continents, as island communities have no alternative solutions in the event of a failure of their water supplies. Those tasked with resource protection and management need access to scientifically sound research that is specific to island environments.

The above issues are universal to island states yet researchers in these far flung and isolated places seldom have the opportunity to share their knowledge and experience with one another. They work largely in isolation. The great distances that separate most island states from larger centers of academia and government means that there is less frequent exchange between researchers on the islands and their colleagues in the major population centers. Enhanced communication and collaboration between island researchers can provide a vital, synergistic link that will strengthen all the researchers' programs. It is a truism that the greatest scientific advances usually result from the collaboration of groups of researchers working together.

There are four island-based research centers within the United States Geological Survey's State Water Resources Institutes program. They form the "Islands Region" of the National Institutes for Water Resources (NIWR), and are (1) the Water Resources Research Center (WRRC) in Honolulu, Hawaii; (2) the Water and Environmental Research Institute (WERI) of the Western Pacific in Mangilao, Guam; (3) the Puerto Rico Water Resources and Environmental Research Institute (WRERI) in Mayaguez, Puerto Rico; and (4) the Virgin Islands Water Resources Research Institute (VI-WRRI) in St. Thomas, U.S. Virgin Islands. Each institute addresses similar issues within its geographic region and yet communication between the institutes is infrequent and difficult due to physical distances and time differences. In addition to the island institutes, there are several other water research initiatives in US and non-US islands and territories—such as American Samoa, Samoa, Fiji, Tonga, and Palau in the Pacific and in several of the islands of the Caribbean—that face similar types of water problems and issues that the US researchers work on.

The island institutes have proposed to organize an intensive 3.5 day meeting in St. Thomas, US Virgin Islands, of representatives from water research institutes on islands—both US and non-US—as an opportunity to share information about research being conducted, research needs perceived, and to plan for collaboration on future research that will address common problems and issues.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2017AS473B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Categories:	Education, None, None
Descriptors:	None
Principal Investigators:	Philip Moravcik

Publication

1. There are no publications for 2017.

Introduction

In 2013, Hawaii's Water Resources Research Center (WRRC) was assigned an added responsibility as the WRRIP Center for American Samoa. American Samoa faces a number of water management issues—both drinking and environmental. In order to effectively address these issues, a degree of understanding and familiarity with the problems stakeholders experience is necessary. An advisory council was created in 2016 to help guide and direct WRRC for future research in American Samoa. This committee was consulted in regard to the selection of studies for funding under the WRRIP program for FY2018. WRRC faculty have engaged in a number of research projects in American Samoa, some of which are ongoing. The results of these studies will be disseminated to American Samoa stakeholders as they become available.

Problem and Research Objectives

The ongoing technology transfer effort in American Samoa seeks to address a perceived lack of scientific and policy knowledge concerning water issues among the general populace. American Samoa has a number of pressing water challenges including (1) providing adequate clean, fresh water to a population that is spread widely (decentralized) across the main island of Tutuila and on the other smaller islands; (2) the proper collection, treatment and disposal of wastewater from these communities; (3) protecting the surface water resources despite of intensive land use; and (4) protecting the precious nearshore marine resources from contamination borne by discharges from the land. The objective is to disseminate the findings of research projects that attempt to address these concerns to (name agencies and/or stakeholders).

WRRC researchers, working on several studies in American Samoa, have engaged the participation and collaboration of local stakeholders from the American Samoa Community College (ASCC), American Samoa Environmental Protection Agency (ASEPA), the American Samoa Power Authority (ASPA), and the American Samoan National Association of State Departments of Agriculture (NASDA).

Technology Transfer Office Activities

The Technology Transfer activities for American Samoa included personal communication with members of the Advisory Committee (regarding?), assisting with the set up of the new online proposal system (name the system), participation in the selection process for choosing internal and external reviewers for the 104B grants for American Samoa, and participation in the review process for the awarding of those grants. Planning for a meeting of WRRC's director with the Advisory Committee in the territory is underway.

American Samoa Advisory Committee Members

- Kelley L. Anderson Tagarino, Extension Faculty, American Samoa Community College/ University of Hawaii Sea Grant
- Utu Abe Malae, Executive Director, American Samoa Power Authority
- Peter Gurr, Deputy Director, American Samoa Department of Agriculture

- Hideyo Hattori, American Samoa Management Liaison, Coral Reef Conservation Program and Coastal Zone Management Program, National Oceanic and Atmospheric Administration Program
- Mark Schmaedick, Entomologist, American Samoa Community College
- Tim Bodell, American Samoa Environmental Protection Agency

travel to American Samoa

Basic Information

Title:	travel to American Samoa
Project Number:	2017AS477B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Categories:	Management and Planning, Law, Institutions, and Policy, Education
Descriptors:	None
Principal Investigators:	Darren T. Lerner

Publication

1. There are no publications for 2017.

Since 2013 the University of Hawaii Water Resources Research Center has managed a research, education, and outreach program for American Samoa. With the administrative hub at the University of Hawaii on the island of Oahu, more than 2,600 miles from Pago Pago, American Samoa, funds have been allocated for travel to conduct program activities. In 2016, a separate advisory council consisting of members of local government agencies, US government agencies operating in American Samoa, nonprofits, non-governmental organizations (NGOs), and community leaders was established to help guide and focus the sparse research funds allocated to this location.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016HI464B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	1st
Research Category:	Not Applicable
Focus Categories:	Education, None, None
Descriptors:	None
Principal Investigators:	Philip Moravcik

Publications

1. Kirs, M., V. Kisand, M. Wong, R.A. Caffaro-Filho, P. Moravcik, V.J. Harwood, B. Yoneyama, and R.S. Fujioka, 2017, “Multiple lines of evidence to identify sewage as the cause of water quality impairment in an urbanized tropical watershed,” Water Research, 116:23–33.
2. Kirs, M., P. Moravcik, P. Gyawali, K. Hamilton, V. Kisand, I. Gurr, C. Shuler, and W. Ahmed, 2017, “Rainwater harvesting in American Samoa: Current practices and indicative health risks,” Environmental Science and Pollution Research, pp. 1–9, doi:10.1007/s11356-017-8858-z.
3. There are no publications for 2017.

Introduction

During FY2017, WRRC continued to further the goal of broadening knowledge and appreciation of Hawaii's water resources. WRRC's Technology Transfer Office (TTO) organized seminars, produced posters and other materials for presentations, and maintained the Center's website. The Technology Transfer Specialist was active in meeting with agency personnel, assisting with proposal writing, research project implementation, and contributing to report authorship for the Center's research projects.

Problem and Research Objectives

The "problems" that this project sought to mitigate include the following: (1) a lack of scientific and policy knowledge concerning water issues among Hawaii's general populace, (2) considerable misinformation about water circulating in the public domain, and (3) a lack of understanding and appreciation of the value of water research conducted at the University among policy makers and governmental agencies in the state. Under this project WRRC sought to redress these problems through our outreach/educational activities. Our objective was to inform the public and governmental agencies to improve the understanding and management of water resources in Hawaii and the region.

Technology Transfer Office Activities

The TTO employed a range of media to disseminate the Center's research through their bulletins and publications; web site; workshops, meetings, and conferences; and regular seminars. All served to aid the Center in transferring information concerning water resource research and issues.

WRRC's TTO activities included:

- Organizing WRRC Spring and Fall seminars
- Participating in research projects, meetings, conferences, school science fairs
- Providing research information and assistance to consultants, students of all levels, and the general public
- Updating the Center's web site with current research activities and information

WRRC Seminars

The TTO organized biweekly seminar series designed to foster communication among WRRC researchers, students, and the organizational target audience of government agencies, private-sector researchers, and members of the general public with an interest in water resource issues. The following is a list of the seminars presented in FY2017.

Spring 2017 Seminar

February 24, 2017	The Influence of Geologic Heterogeneity on Large-Scale Groundwater Flow and Solute Transport: Continental Shelves and Mega-Cities Speaker: Holly Michael
March 16, 2017	New Approach in the Monitoring of Temporal Changes in the Freshwater-Saltwater Interface; Case Study and its Future Application Speaker: Yongcheol Kim
May 3, 2017	Density-Driven Groundwater Flow: Seawater Intrusion, Natural Convection, and Other Phenomena Speaker: Cliff Voss
May 11, 2917	Model-Based Management of Groundwater Resources Under Uncertainty Speaker: Ahmed S. Elshall

Fall 2017 Seminar

August 2, 2017	HWEA/WRRC/Seagrant Workshop: Green Energy in the Wastewater Industry: Moving Toward Net Zero Energy In Hawaii
August 10, 2017	Hydrological Modeling in Alpine Catchments on the Tibetan Plateau Speaker: Fan Zhang
September 6, 2017	Bayesian Model Selection of Microbial Soil Respiration Model Speaker: Ahmed S. Elshall
September 20, 2017	Managing for Island Resilience Through Scenario Planning with Linked Land-Sea Models Speaker: Jade Delevaux
October 4, 2017	We Punch Nature and it Will punch Us Back; the Feedbacks of Climate Change on People Speaker: Camilo Mora
October 18, 2017	Subsurface Characterization with an Application to Coastal Aquifer Characterization Speaker: Jonghyun Harry Lee
October 27, 2017	Case Studies on Groundwater Augmentation in Korea Under Changing Climate: Application Potential to the Hawaiian Islands Speaker: Yongcheol Kim

November 1, 2017	The Role of Science in Water-Resource Management in Hawaii and the Pacific Speaker: Steve Anthony
November 15, 2017	Down in the Weeds: Estimating Sediment Export to Inform Management Speaker: Kim Falinski
December 6, 2017	West Maui Coastal Nutrient Loads From Groundwater Discharge — History and Recent Developments Speaker: Robert Whittier

WRRC Website

The Center's website (www.wrrc.hawaii.edu) is continuously updated with information about WRRC's research activities, seminars, reports, meetings, grant announcements, and the Center's L. Stephen Lau scholarship fund. The site provides information about the Center's facilities and personnel as well as a database for WRRC's publications. A web-site search function provides easy access to the available information.

Digitization and Online Posting of Center Publications

The Center continues to provide their published material as they become available to the University of Hawaii at Manoa's ScholarSpace institutional repository database. These reports are available for download in a PDF format at http://scholarspace.manoa.hawaii.edu/.

Poster Production

Poster design and production services were provided to the Center's faculty and graduate research assistants for presentations at meetings and conferences.

Editing

Editorial services for a number of reports and articles were provided during the reporting period. This work helps to disseminate the Center's research results through journals and other publications.

L. Stephen Lau Scholarship

Application review, and applicant selection for the Center's L. Stephen Lau Scholarship is coordinated through the TTO. This scholarship is made annually thanks to an endowment by former WRRC Director L. Stephen Lau and his wife Virginia.

WRRIP 104B Grants

The TTO participated in the review and selection for funding of research proposals made under the 2017 WRRIP 104B grant program.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	10	0	0	0	10
Masters	9	0	0	0	9
Ph.D.	4	0	0	0	4
Post-Doc.	3	0	0	1	4
Total	26	0	0	1	27

Notable Awards and Achievements

Chris Shuler, the student supported on project 2017AS471B won the Toby Lee award in Geology and Geophysics from the ARCS Foundation for 2018, and the University of Hawaii Foundation's Scholar of the Year Award.

Eric Welch, the student supported on project 2016AS455B won First Place in Natural Sciences Oral Presentations at UH Manoa’s Undergraduate Showcase

Under project 2017AS477B, for the first time an Advisory Council was established to represent American Samoa needs and interests.